Multivariate Time Series Analysis of Line P Hydrographic/STD Data, January 1959 - June 1981.

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Canadian Data Report Of Hydrography and Ocean Sciences

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Les établissements des Sciences et Levés océaniques dans les régions et à l'administration centrale ont cessé de publier leurs diverses séries de rapports depuis décembre 1981. Vous trouverez dans l'index des publications du volume 38 du *Journal canadien des sciences halieutiques et aquatiques*, la liste de ces publications ainsi que le dernier numéro paru dans chaque catégorie. La nouvelle série a commencé avec la publication du Rapport n° 1 en janvier 1982.

Canadian Data Report of Hydrography and Ocean Sciences No. 42

1985

MULTIVARIATE TIME SERIES ANALYSIS OF LINE P HYDROGRAPHIC/STD DATA, JANUARY 1959 - JUNE 1981

by

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ABSTRACT

Bennett, A.F. and J.L. Peart. 1985. Multivariate time series analysis of Line P hydrographic/STD data, January 1959 - June 1981.

Hydrographic/STD data described by Tabata and Peart (1985a,b,c) have been subjected to multivariate time series analysis. After removal of nonstationary components, spatial covariance and correlation matrices were estimated. Principal components, their amplitudes, statistics and power spectra were calculated. Selected results are shown in this report in graphical form. Complete instructions are included for accessing the entire data set and analysis programs.

key words: Line P, Hydrographic Data, Time Series, Multivariate Analysis.

RÉSUMÉ

Les données hydrographiques/STD décrites par Tabata et Peart (1985a, b et c) ont été soumises à une analyse de série chronologique à plusieurs variables. Après avoir éliminé les composantes non stationnaires, on à etabli des matrices de covariance et de corrélation spatiales. On a calculé les composantes principales, leurs amplitudes, des paramètres statistiques et des spectres de puissance. Certains résultats sont présentés dans ce rapport sous une forme graphique. On a joint des instructions complètes pour accéder à l'ensemble complet des données et aux programmes d'analyse.

mots clés: Line P, Données Hydrographiques, Série Chronologique, Analyse à Plusiers Variables.

INTRODUCTION

Hydrographic and STD casts were made at 13 stations along Line P for approximately 22-1/2 years (January 1959 - June 1981). Detailed descriptions and univariate statistical analyses of the data may be found in Tabata and Peart (1985a,b and c). Multivariate time-series analyses have also been made. Selected results of these multivariate analyses are included in this report in graphical form, plus detailed instructions for accessing all results which are all available on magnetic tape at IOS.

DATA AND ANALYSES

The entire analysis is described below; selected results are included in graphical form with fully descriptive captions.

§1

This analysis was restricted to so-called "derived quantities": dynamic height relative to the sea surface (Delta-D) on standard pressure surfaces, potential temperature (Theta) on standard pressure surfaces, and acceleration potential relative to the 1000 dbar surface (Acc. Pot.) on standard specific gravity anommaly (Sigma-T) surfaces. Every station was included but a few standard levels were discarded at every station due to insufficient samples being available. In all, 181 station pressure grid-points were retained, while 154 station-Sigma-T grid points
Fig. 1,2 were retained.

§2

The time-series of observations at each grid-point are irregularly spaced in time, and not every grid-point was sampled at every time. As a result, sample covariance matrices (see §4 below) were non-positive to a significant degree. Hence each time-series was interpolated linearly in time to the finest,
Fig. 3 common irregular time base. This yielded positive covariance matrices.

§3

The time-series were reduced to pseudo-stationary residuals by least-squares fitting and removal of the following functional forms:

a) a constant;
b) a linear trend;
c) a semi-annual cycle; and
d) an annual cycle.

The following parameters are available for these fits:

Fig. 4 i) the mean;
Fig. 5,6 ii) the total increment in the linear trend;
Fig. 7,8 iii) the semi-annual amplitude and phase;
Fig. 9,10,11 iv) the annual amplitude and phase; and
Fig. 12 v) the residual r.m.s.

§4

The pseudo-stationary time-series at the grid-points form a multivariate time series with 181 or 154 components. The sample covariance and correlation matrices are available, as are their
Fig. 13-18 eigenvalues and eigenvectors or principal components.

§5

The time-series of principal component amplitudes are available. The following statistics are available for each of the leading amplitude time-series, and also for some of the grid-point time series

Fig. 19-47

a) the skewness;
b) the kurtosis;
c) the Kolmogorov-Smirnov D test statistic for the null hypothesis of univariate normality with mean and variance unknown;
d) the probability that the null hypothesis is valid;
e) the probability plot; and
f) the power spectra, calculated by harmonic analysis with 80 frequencies equi-spaced by .04125 cycles per month, from 1/200 c.p.m. to 1/3 c.p.m.

§6

Various analyses have been carried out in order to explore the influences of the irregular time bases, and the linear interpolation to the finest irregular time base. A few of these results have been kept:

Fig. 48,49

i) Theta: power spectrum for the amplitude of the first and second principal components (covariance matrix). Only time intervals > 1.5 months were allowed.

Fig. 50,51

ii) Sigma-T: (Station 2, 100 dbar). An N(0,1) random number was generated for each time in the original time series of real observations (113 values; mean = 0.1642, standard deviation = 1.035). These were interpolated linearly to the finest irregular time base (223 values in all). The

Fig. 50,51

interpolated random time series and power spectrum are shown here.

Fig. 52,53

iii) As for (ii) above, but the interpolated time series was made pseudo-stationary as in §3 above. The residual time series and residual power spectrum are shown here.

REFERENCES

Tabata, S. and J.L. Peart. 1985a. Statistics of Oceanographic Data Based on Hydrographic/STD Casts Made at Ocean Station P During August 1956 Through June 1981. Canadian Data Report of Hydrography and Ocean Sciences, No. 31, 133 pp.

Tabata, S. and J.L. Peart. 1985b. Statistics of Oceanographic Data Based on Hydrographic/STD Casts Made at Stations 1 Through 6 Along Line P During January 1959 Through June 1981. Canadian Data Report of Hydrography and Ocean Sciences, No. 38, 447 pp.

Tabata, S. and J.L. Peart. 1985c. Statistics of Oceanographic Data Based on Hydrographic/STD Casts Made at Stations 7 Through 12 Along Line P During January 1959 Through June 1981. Canadian Data Report of Hydrography and Ocean Sciences, No. 43, 402 pp.

Tape formats and file contents

LINE P: MULTIVARIATE TIME SERIES ANALYSIS

TAPE U01548 DESCRIPTION

GENERAL:

Unlabelled, ASCII, 1600 BPI, 81 Files, Record Length = 80, Blocks = 50 Records

Sections:

A	Files	1-21	Fortran Programmes
B	File	22	Sample Runstreams in UNIVAC 1100 ECL
C	File	23	Description of Cruise Vector Layouts
D	Files	24-29	Standard Pressure Data Files
E	Files	30-44	Delta-D, at Standard Pressures, Data Files
F	Files	45-59	Theta, at Standard Pressures, Data Files
G	Files	60-65	Standard Sigma-T Data Files
H	Files	66-80	Acceleration Potential, at Standard Sigma-T's, Data Files
I	File	81	Theta Coefficient Data File, Minimum 1.5 Month Cruise Separations

LINE P: MULTIVARIATE TIME SERIES ANALYSIS

TAPE UO1548 DESCRIPTION

FILE DESCRIPTIONS

#	NAME	RECORDS	BLOCKS	DESCRIPTION
A:	Fortran Programmes			
1	UNFORMAT	137	3	Takes any data file after unblocking and reformats the data for input into the other programmes.
2	SELECTION1	207	5	Selects from the derived quantities tape four values at each standard Line-P station at either standard pressures or standard sigma-t surfaces.
3	SELECTION2	317	7	Creates one vector for each outgoing and incoming cruise of all data saved from the 'selection1' programme. Vectors are rejected which have been flagged by the user.
4	DATE	137	3	Creates a time series of cruise dates based on the vectors generated by the 'selection2' programme.
5	REDUCE	364	8	Reduces the length of each cruise vector by rejecting elements which have too many voids in the time series.
6	INTERPOLATE	118	3	Fills all void elements by linear interpolation.
7	PRESORT	77	2	Sorts the interpolated Line-P file and the cruise date file into ascending order and averages cruise vectors which have the same mid-point date.
8	DETREND	649	13	Subtracts from each element in a time series the mean, linear trend, 6 month and 12 month components.
9	ABAR	151	4	Calculates a mean for each time series element.
10	COVARIANCE	181	4	Calculates the covariance matrix.
11	CONVERT	27	1	Converts the covariance matrix from double precision to single precision.
12	CORRELATION	43	1	Calculates the correlation matrix.
13	EIGEN	104	3	Calculates the eigen values and vectors.
14	COEFF	167	4	Calculates the coefficient cruise vectors using the 'detrend' residual file and the calculated eigen vectors.
15	POWERSPEC	993	20	Calculates and plots the power spectra for selected cruise vector elements.
16	TIMESERIES	435	9	Plots the time series for any element.
17	KOLMOGOROV	664	14	Performs the Kolmogorov-Smirnov one-sided d-statistic test on any or all time series, and plots or stores the results.

18	CONTOUR	1742	35	Contours the elements of a specified vector.
19	EIGENPLT	201	5	Plots a cumulative graph of eigen values.
20	STATPLT	157	4	Plots the Kolmogorov-Smirnov results.
21	6WEEK	35	1	Selects from a given time series only those cruises which have a greater than 1.5 month separation.
B:	Runstreams			
22	RUNSTREAMS	989	20	Sample runstreams in UNIVAC ECL for running any of the supplied programmes.
C:	FStructure			
23	FSTRUCTURE	72	2	Description of cruise vector layouts.
D:	Line P at Standard Pressures			
24	P-LINEP	34505	691	Line P, standard pressure time series output from 'selection2'.
25	P-DATE	228	5	Mid-point date of each cruise vector in 'p-linep' data file.
26	P-REDUCED	27468	550	Standard pressure time series after selected vector elements removed.
27	P-INTERP	27468	550	Time series after all void values satisfied.
28	P-SORTED	26863	538	Time series sorted into ascending order.
29	P-DATES	223	5	'P-date' file sorted into ascending order.
E:	Delta-D at Standard Pressures			
30	D-RESID	6883	138	Residuals after detrending.
31	D-MEAN2	32	1	Mean values removed by 'detrend'.
32	D-STEP	32	1	Linear trends removed by 'detrend'.
33	D-6AMP	32	1	6 month amplitudes removed by 'detrend'.
34	D-6PHA	32	1	6 month phases removed by 'dtrend'.
35	D-12AMP	32	1	12 month amplitudes removed by 'detrend'.
36	D-12PHA	32	1	12 month phases removed by 'detrend'.
37	D-FNORM	32	1	Residual variances after components removed.
38	D-DSTAT	364	8	Kolmogorov-Smirnov test results on 'd-resid'.
39	D-VEIGEN	436	0	Eigen values and vectors of covariance matrix.
40	D-VCOEF	668	14	Coefficients generated from 'd-resid' and 'd-veigen'.
41	D-VSTAT	30	1	Kolmogorov-Smirnov test results on 'd-vcoef'.

42	D-REIGEN	498	10	Eigen values and vectors of correlation matrix.
43	D-RCOEF	668	14	Coefficieints generated from 'd-resid' and 'd-reigen'.
44	D-RSTAT	34	1	Kolmogorov-Smirnov test results on 'd-rcoef'.

F: Theta at Standard Pressures

45	T-RESID	6883	138	Residuals after detrending.
46	T-MEAN2	32	1	Mean values removed by 'detrend'.
47	T-STEP	32	1	Linear trends removed by 'detrend'.
48	T-6AMP	32	1	6 month amplitudes removed by 'detrend'.
49	T-6PHA	32	1	6 month phases removed by 'detrend'.
50	T-12AMP	32	1	12 month amplitudes removed by 'detrend'.
51	T-12PHA	32	1	12 month phases removed by 'detrend'.
52	T-FNORM	32	1	Residual variances after components removed.
53	T-DSTAT	364	8	Kolmogorov-Smirnov test results on 't-resid'.
54	T-VEIGEN	436	9	Eigen values and vectors of covariance matrix.
55	T-VCOEF	668	14	Coefficients generated from 't-resid' and 't-reigen'.
56	T-VSTAT	30	1	Kolmogorov-Smirnov test results on 't-vcoef'.
57	T-REIGEN	498	10	Eigen values and vectors of correlation matrix.
58	T-RCOEF	668	14	Coefficients generated from 't-resid' and 't-reigen'.
59	T-RSTAT	34	1	Kolmogorov-Smirnov test results on 't-rcoef'.

G: Line P at Standard Sigma-T Surfaces

60	S-LINEP	39499	790	Line P, standard Sigma-t surface time series, output from 'selection2'.
61	S-DATE	228	5	Mid-point date of each cruise vector in 's-linep' data file.
62	S-REDUCED	23382	468	Standard pressure time series after selected vector elements removed.
63	S-INTERP	23382	468	Time series after all void values satisfied.
64	S-SORTED	22970	460	Time series sorted into ascending order.
65	S-DATES	224	5	'S-date' file sorted into ascending order.

H: Acceleration Potential at Standard Sigma-T's

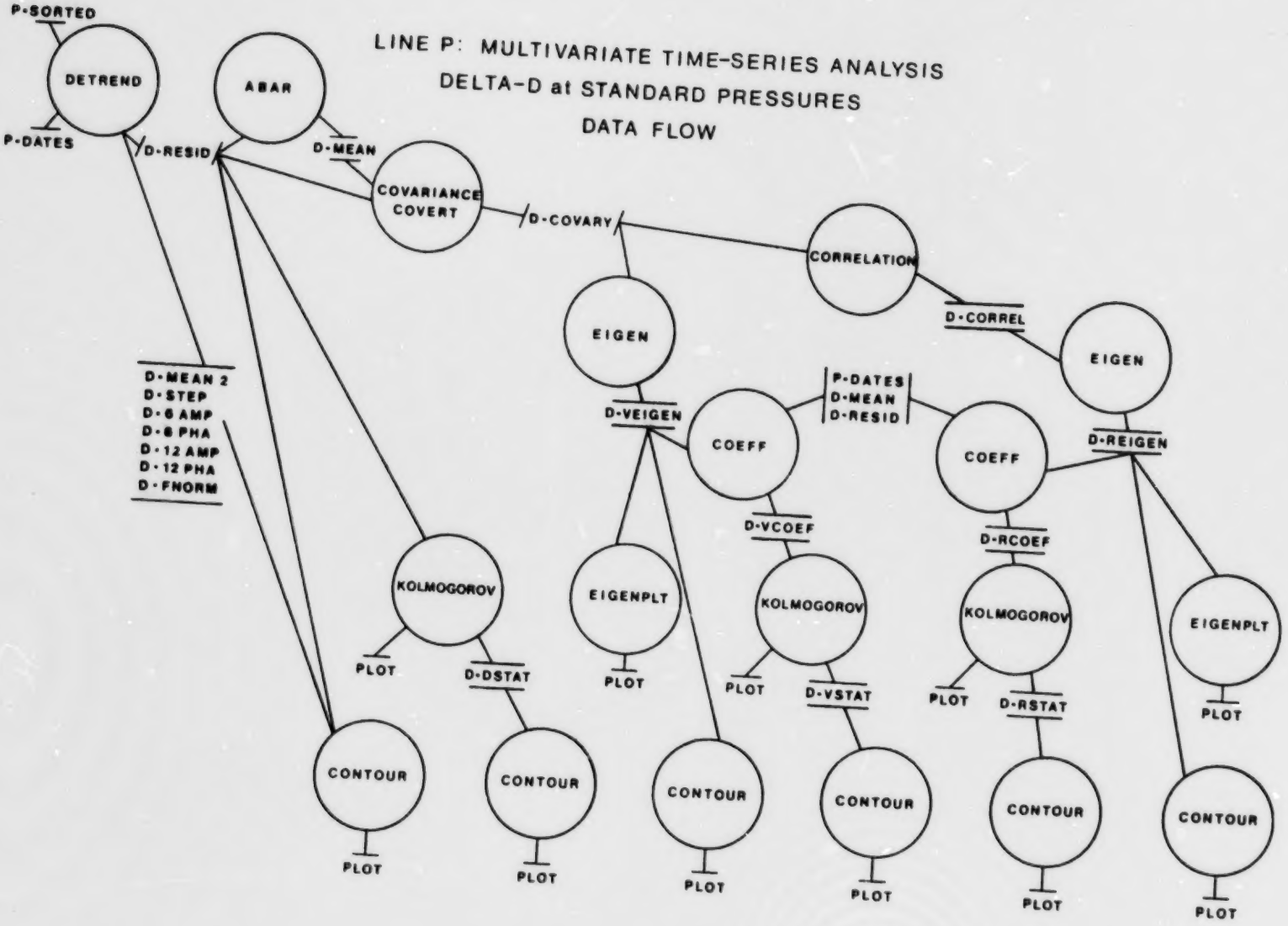
66	A-RESID	5799	116	Residuals after detrending.
67	A-MEAN2	27	1	Mean values removed by 'detrend'.
68	A-STEP	27	1	Linear trends removed by 'detrend'.

69	A-6AMP	27	1	6 month amplitudes removed by 'detrend'.
70	A-6PHA	27	1	6 month phases removed by 'detrend'.
71	A-12AMP	27	1	12 month amplitudes removed by 'detrend'.
72	A-12PHA	27	1	12 month phases removed by 'detrend'.
73	A-FNORM	27	1	Residual variances after components removed.
74	A-DSTAT	310	7	Kolmogorov-Smirnov test results on 'a-resid'.
75	A-VEIGEN	418	9	Eigen values and vectors of covariance matrix.
76	A-VCOEF	448	9	Coefficients generated from 'a-resid' and 'a-veigen'.
77	A-VSTAT	22	1	Kolmogorov-Smirnov test results on 'a-vcoef'.
78	A-REIGEN	418	9	Eigen values and vectors of correlation matrix.
79	A-RCOEF	448	9	Coefficients generated from 'a-resid' and 'a-reigen'.
80	A-RSTAT	22	1	Kolmogorov-Smirnov test results on 'a-rcoef'.

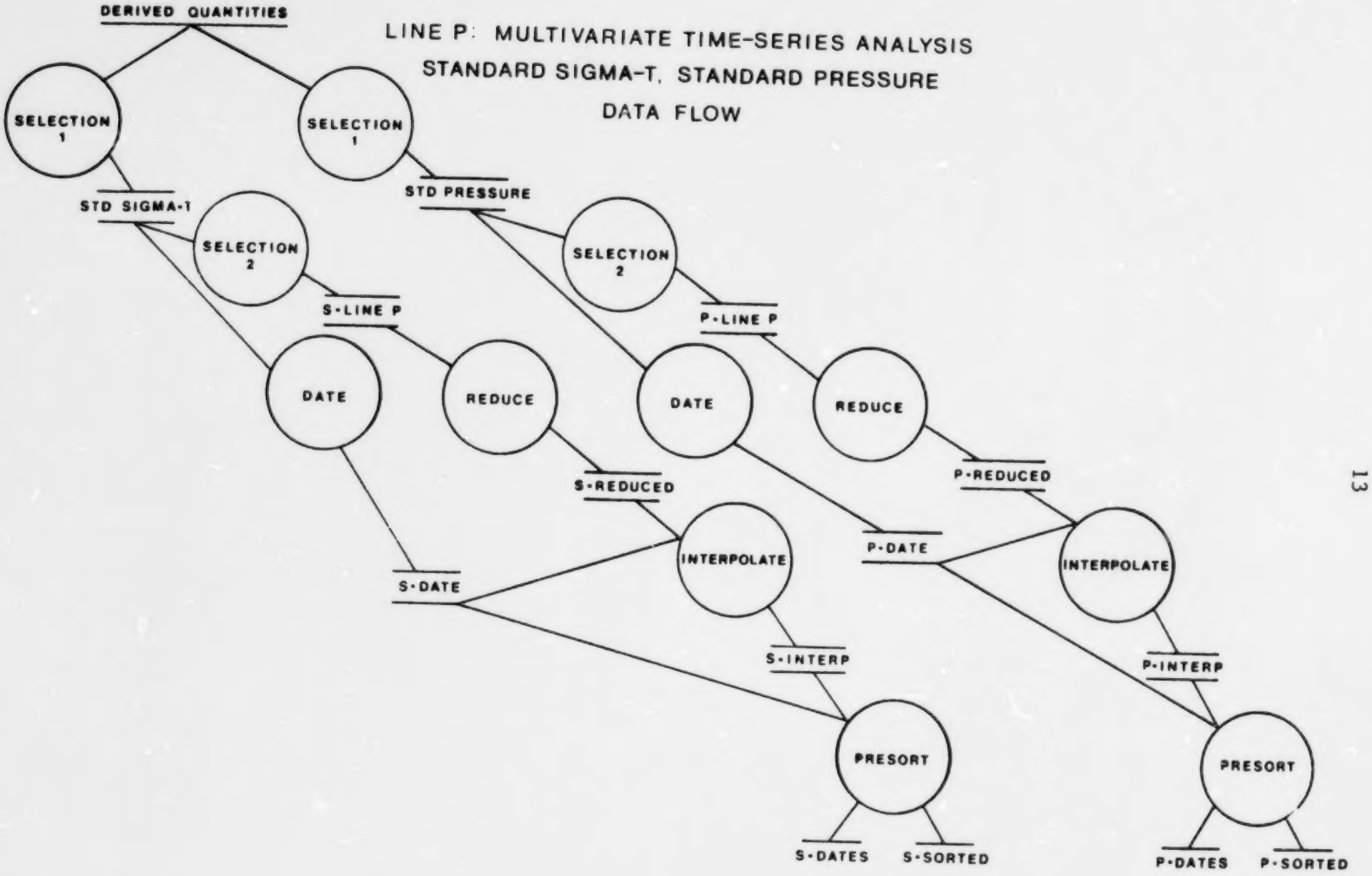
I: Theta Coefficients at 6 Weeks

81	AB-6WEEK	670	14	Theta coefficient data file with minimum 1.5 cruise separations.

Flow Charts for I/O


LINE P: MULTIVARIATE TIME-SERIES ANALYSIS
DELTA-D at STANDARD PRESSURES
DATA FLOW
P-SORTED
DETREND
P-DATES
D-RESID
ABAR
D-MEAN
COVARIANCE
COVERT
D-COVARY
CORRELATION
D-CORREL
D-MEAN 2
D-STEP
D-6 AMP
D-6 PHA
D-12 AMP
D-12 PHA
D-FNORM
EIGEN
D-VEIGEN
COEFF
P-DATES
D-MEAN
D-RESID
COEFF
EIGEN
D-REIGEN
D-VCOEF
D-RCOEF
KOLMOGOROV
PLOT
D-DSTAT
EIGENPLT
PLOT
KOLMOGOROV
PLOT
D-VSTAT
KOLMOGOROV
PLOT
D-RSTAT
EIGENPLT
PLOT
CONTOUR
PLOT
CONTOUR
PLOT
CONTOUR
PLOT
CONTOUR
PLOT
CONTOUR
PLOT
CONTOUR
PLOT

LINE P: MULTIVARIATE TIME-SERIES ANALYSIS
STANDARD SIGMA-T, STANDARD PRESSURE
DATA FLOW



File Layouts ⇒

PROJECT: LINE P: MULTIVARIATE TIME-SERIES ANALYSIS

C: LAYOUT OF FORMATTED FILES (Record Length=80)

ALL FILE TYPES

Record 1

I2	I4	A72					
File Type	LENV (Vector Length)	HEADER (File Description)					
1 2	4 7	9 80					

FILE TYPES 3,4

Record 2

I5							
#of Records or Vector Length							
1 5							

FILE TYPE 1

Part 1 of Each Unformatted Record

I7	A7	5E13.5					
Cruise Identifier	Cruise Label	Vector (1-5)					
1 7	9 15	16 80					

FILE TYPE 3

Part 1 of Each Unformatted Record

E13.5	5E13.5						
Mean or Eigen Value	Vector (1-5)						
1 13	14 78						

PROJECT: LINE P: MULTIVARIATE TIME-SERIES ANALYSIS

C: LAYOUT OF FORMATTED FILES (Con't)

FILE TYPE 4

Part 1 of Each Unformatted Record

A7	E13.5	4E13.5					
Cruise Label	Date of Cruise	Vector (1-4)					
2 8	9 21	22 73					

ALL FILE TYPES

All Remaining Records

6E13.5							
Vector (⟶ LENV)							
1 78							

PROJECT: LINE P: MULTIVARIATE TIME-SERIES ANALYSIS

D: LAYOUT OF UNFORMATTED FILES

File Type 1 - One Record type
- Includes all Date files, all Line P at Standard Pressure files, all Line P at Standard Sigma-T files and all 'DETREND' Residual files

GENERAL LAYOUT

I*4	A7	R*4					
Cruise ID	Cruise Label	Vector (LENV)					
1	2	3 LENV+2					

P-LINEP (LENV=908)

I*4	A7	R*4	R*4	R*4	R*4		
Cruise ID	Cruise Label	Sigma-T (227)	Theta (227)	Delta-D (227)	Acceleration Potential (227)		
1	2	3 229	230 456	457 683	684 910		

P-REDUCED
P-INTERP
P-SORTED (LENV=724)

I*4	A7	R*4	R*4	R*4	R*4		
Cruise ID	Cruise Label	Sigma-T (181)	Theta (181)	Delta-D (181)	Acceleration Potential (181)		
1	2	3 183	184 364	365 545	546 726		

D-RESID
T-RESID (LENV=181)

I*4	A7	R*4					
Cruise ID	Cruise Label	Delta-D or Theta (181)					
1	2	3 183					

PROJECT: LINE P: MULTIVARIATE TIME-SERIES ANALYSIS

File Type 1 (Con't)

P-DATE
P-DATES
S-DATE
S-DATES
(LENV=1)

I*4	A7	R*4					
Cruise ID	Cruise Label	Cruise Date (months)					
1	2	3					

S-LINEP
(LENV=1040)

I*4	A7	R*4	R*4	R*4	R*4		
Cruise ID	Cruise Label	Pressure (260)	Theta (260)	Delta-D (260)	Acceleration Potential (260)		
1	2	3 262	263 522	523 782	783 1042		

S-REDUCED
S-INTERP
S-SORTED
(LENV=616)

I*4	A7	R*4	R*4	R*4	R*4		
Cruise ID	Cruise Label	Pressure (154)	Theta (154)	Delta-D (154)	Acceleration Potential (154)		
1	2	3 156	157 310	311 464	465 618		

A-RESID
(LENV=154)

I*4	A7	R*4					
Cruise ID	Cruise Label	Acceleration Potential (154)					
1	2	3 156					

PROJECT: LINE P: MULTIVARIATE TIME-SERIES ANALYSIS

D: LAYOUT OF UNFORMATTED FILES (Con't)

File Type 2 - One Record/File containing one Vector of Length = LENV
- Includes all component files generated by 'DETREND'

GENERAL LAYOUT

R*4							
Vector (LENV)							
1 LENV							

D-,T-MEAN2
D-,T-STEP
D-,T-6AMP
D-,T-6PHA
D-,T-12AMP
D-,T-12PHA
D-,T-FNORM

R*4							
Vector (181)							
1 181							

A-MEAN2
A-STEP
A-6AMP
A-6PHA
A-12AMP
A-12PHA
A-FNORM

R*4							
Vector (154)							
1 154							

PROJECT: LINE P: MULTIVARIATE TIME-SERIES ANALYSIS

File Type 3 - Two Record types
- Includes 'KOLMOGOROV' D-Statistic files and 'EIGEN' Eigen Value files

GENERAL LAYOUT

Record 1

I*4							
NREC (#of Records to follow)							
1							

Records 2→NREC + 1

R*4							
Vector (LENV+1)							
1 LENV+1							

(1 Record for each element in a Cruise Vector)

D-D, D-V, D-RSTAT
T-D, T-V, T-RSTAT
(LENV=7)
Records 2→182
A-D, A-V, A-RSTAT
(LENV=7)
Records 2→155

R*4	R*4	R*4	R*4	R*4	R*4	R*4	R*4
Mean	Standard Deviation	D-Statistic	Probability	3rd Moment	4th Moment	Kurtosis	Skew
1	2	3	4	5	6	7	8

(Eigen Value (1)=Least Significant, Eigen Value (NREC)=Most Significant)

D-V, D-REIGEN
T-V, T-REIGEN
(LENV=181)
Records 2-NREC+1
A-V, A-REIGEN
(LENV=154)

R*4	R*4						
EIGENVALUE	EIGENVECTOR (LENV)						
1	2 LENV+1						

PROJECT: LINE P: MULTIVARIATE TIME-SERIES ANALYSIS

D: LAYOUT OF UNFORMATTED FILES (Con't)

File Type 4 - Two Record types
- Includes all the Coefficient files
- Record 2 Coefficients calculated from the Most Significant Eigenvector

GENERAL LAYOUT

Record 1

I*4							
LENV (Length of Vectors)							

Records 2 ⟶

A7	R*4	R*4					
Cruise Label	Cruise Date (months)	COEFF (LENV)					
1	2	3 LENV+2					

Records 2 ⟶

D-V, D-RCOEF
T-V, T-RCOEF
(LENV=181)

A7	R*4	R*4					
Cruise Label	Cruise Date (months)	COEFF (181)					
1	2	3 183					

Records 2 ⟶

A-V, A-RCOEF
(LENV=154)

A7	R*4	R*4					
Cruise Label	Cruise Date (months)	COEFF (154)					
1	2	3 156					

FIGURE 1 PRESSURES AT EACH STATION

PRESS	1	2	3	4	5	6	7	8	9	10	11	12	13	TOTAL
50.	124	138	166	136	153	156	138	127	137	119	116	134	144	1788
75.	117	138	166	136	153	156	138	127	137	119	116	134	144	1781
100.	94	116	166	136	153	156	138	127	137	119	116	134	144	1736
125.	18	12	165	136	153	155	138	127	137	119	116	134	144	1554
150.	0	8	165	136	153	155	138	126	136	119	116	134	144	1530
200.	0	6	165	136	152	154	138	126	136	119	116	134	144	1526
250.	0	5	164	136	152	154	138	126	136	119	116	134	144	1524
300.	0	5	164	135	150	154	138	126	136	119	116	134	142	1519
400.	0	4	156	131	144	149	132	119	129	114	110	131	113	1432
500.	0	3	153	128	130	148	114	98	119	96	106	114	105	1314
600.	0	3	153	127	130	146	114	98	119	95	106	114	103	1308
700.	0	1	152	127	130	145	113	97	117	93	106	113	102	1296
900.	0	0	151	126	128	145	113	95	116	93	106	113	102	1288
1000.	0	0	144	125	128	145	113	94	116	93	106	113	102	1279
1200.	0	0	119	124	125	143	113	93	114	93	103	112	102	1241
1500.	0	0	3	109	112	131	103	82	101	82	94	91	90	998
2000.	0	0	0	32	34	19	20	10	46	8	21	10	22	222
2500.	0	0	0	27	10	4	6	4	31	6	9	7	14	118
3000.	0	0	0	0	0	0	4	4	29	6	9	7	14	73
3500.	0	0	0	0	0	0	0	0	27	6	5	7	13	58
4000.	0	0	0	0	0	0	0	0	0	0	0	1	13	14
4200.	0	0	0	0	0	0	0	0	0	0	0	0	9	9

LEAST PRESSURES IN ONE CRUISE: 5
MOST PRESSURES IN ONE CRUISE: 187

NUMBER OF OCCURRENCES OF EACH STATION

1	2	3	4	5	6	7	8	9	10	11	12	13
124	138	166	136	153	156	138	127	137	119	116	134	144

FIGURE 2 SIGMA-T AT EACH STATION

SIG T	1	2	3	4	5	6	7	8	9	10	11	12	13
22000	0	0	0	0	0	0	0	0	0	0	0	0	0
22200	0	0	0	0	0	0	0	0	0	0	0	0	0
22400	0	0	0	0	0	0	0	0	0	0	0	0	0
22600	1	2	0	0	0	0	0	0	0	0	0	0	0
22800	2	3	0	0	0	0	0	0	0	0	0	0	0
23000	3	4	3	1	1	0	0	0	0	0	0	0	0
23200	7	5	4	2	3	1	0	0	0	0	0	0	0
23400	9	13	7	3	6	2	0	0	0	0	0	0	0
23600	23	21	15	10	13	5	2	1	1	0	0	0	1
23800	32	40	34	27	24	14	7	2	1	0	0	0	1
24000	42	53	47	37	38	28	21	9	2	0	0	0	2
24200	51	66	65	51	47	48	31	22	19	8	4	4	40
24400	71	85	77	61	59	63	38	32	29	16	17	16	192
24600	92	100	94	68	66	69	45	35	35	27	23	23	378
24800	114	118	113	85	84	81	55	41	41	34	29	28	684
25000	122	127	140	104	96	99	68	55	53	41	35	39	944
25200	118	129	155	124	120	121	88	69	71	48	42	52	1278
25400	114	126	170	146	145	148	112	93	94	73	59	68	1661
25600	109	117	170	148	158	172	136	118	128	106	86	103	2296
25800	101	104	170	148	158	176	141	129	145	128	110	134	3239
26000	85	91	169	148	158	176	141	129	145	133	118	152	3751
26200	68	81	169	148	158	176	141	128	145	133	118	152	3758
26400	41	61	169	148	158	176	141	128	145	133	118	152	3758
26600	6	21	169	148	157	175	141	128	145	133	118	152	3749
26800	0	3	165	143	151	175	140	127	144	133	118	152	3617
27000	0	3	157	138	135	169	119	104	132	120	111	145	2489
27200	0	1	156	137	135	167	117	99	125	104	108	128	2165
27400	0	0	123	131	133	163	116	96	121	104	108	128	2112
27600	0	0	0	39	43	26	23	15	54	10	28	17	628
27800	0	0	0	0	0	0	0	0	0	0	0	0	8

FIGURE 3

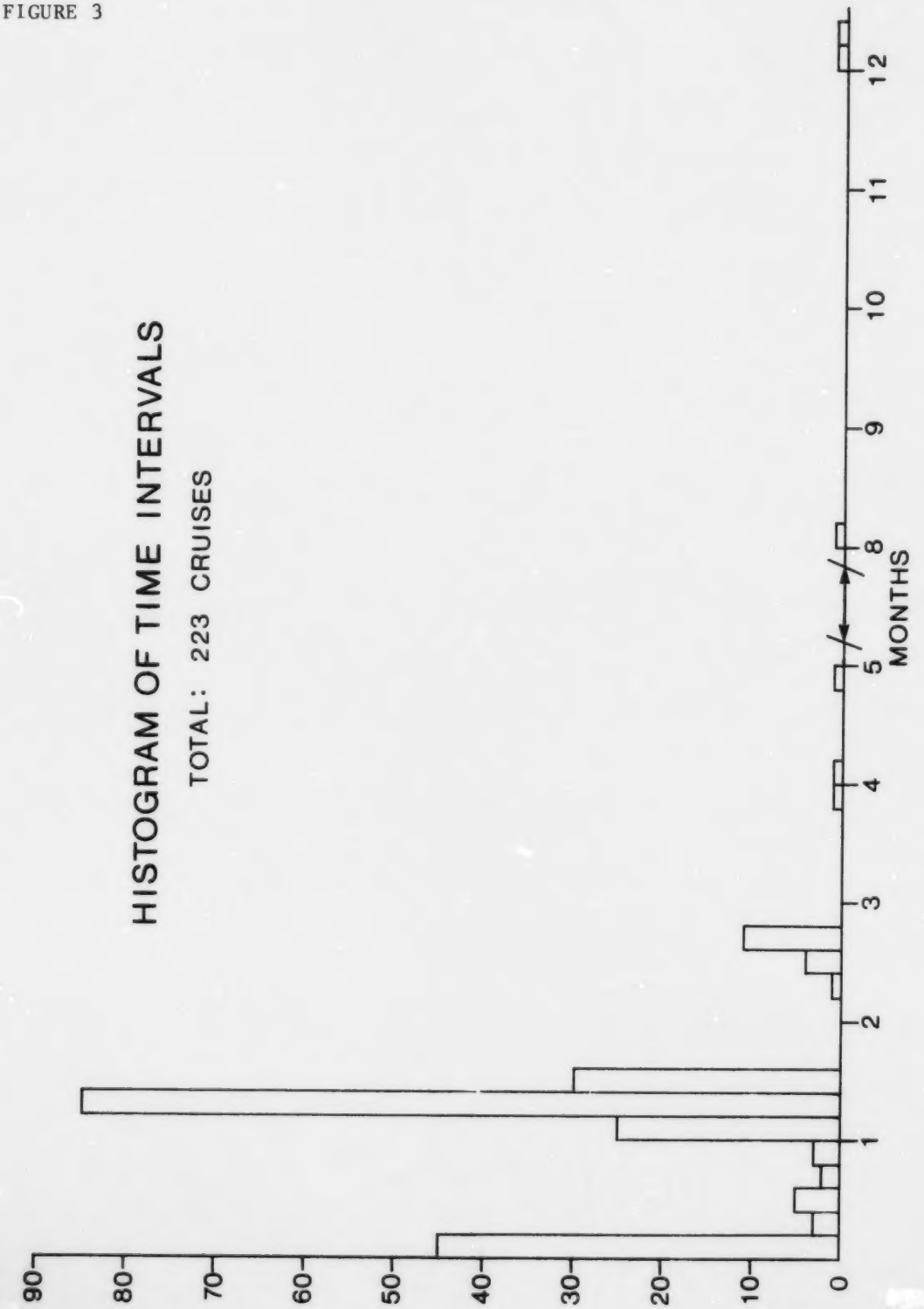

HISTOGRAM OF TIME INTERVALS
TOTAL: 223 CRUISES
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
8
9
10
11
12
MONTHS

FIGURE 4

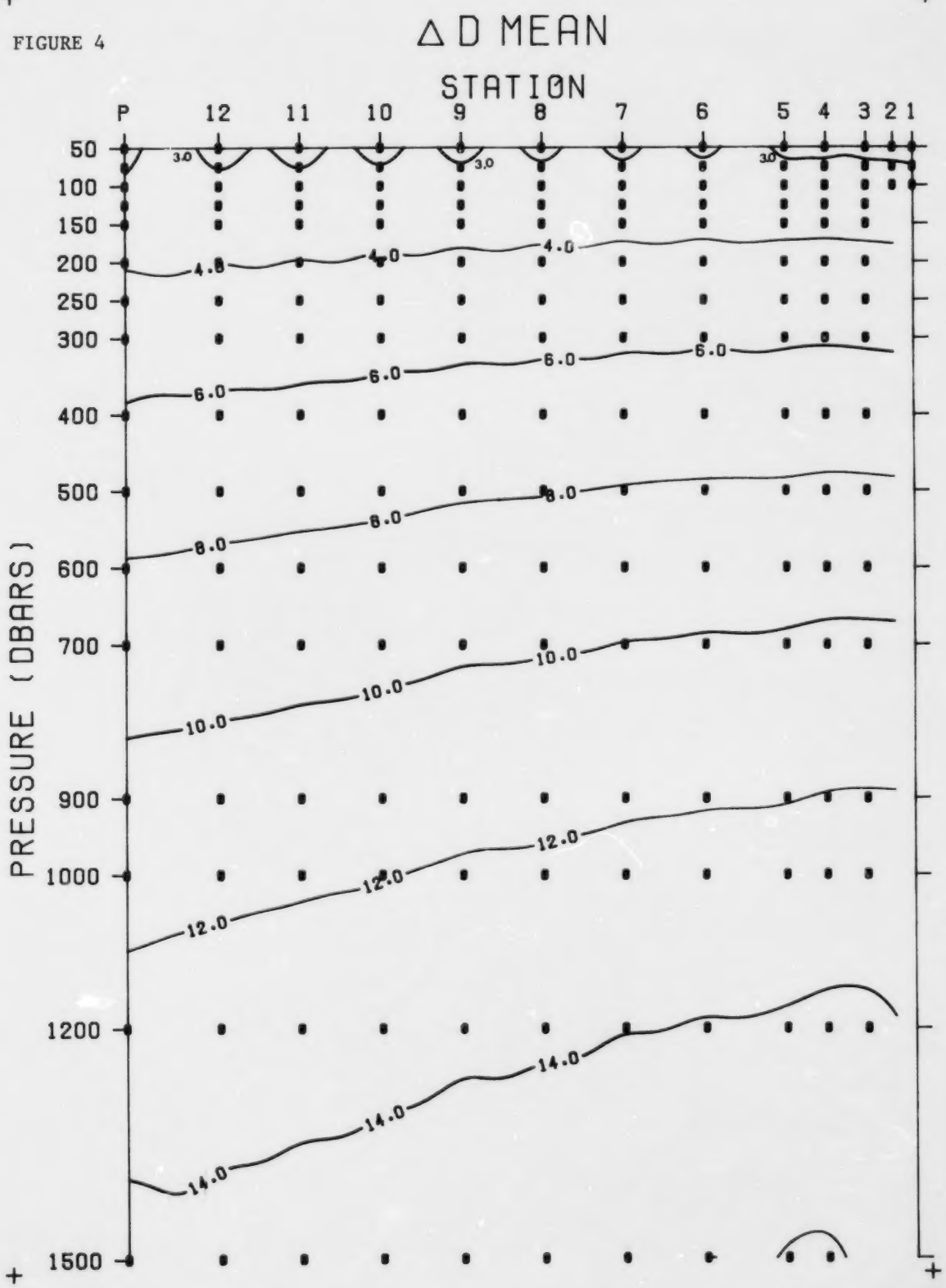

Δ D MEAN
STATION
P 12 11 10 9 8 7 6 5 4 3 2 1
PRESSURE (DBARS)
50
100
150
200
250
300
400
500
600
700
900
1000
1200
1500
3.0
4.0
6.0
8.0
10.0
12.0
14.0

FIGURE 5

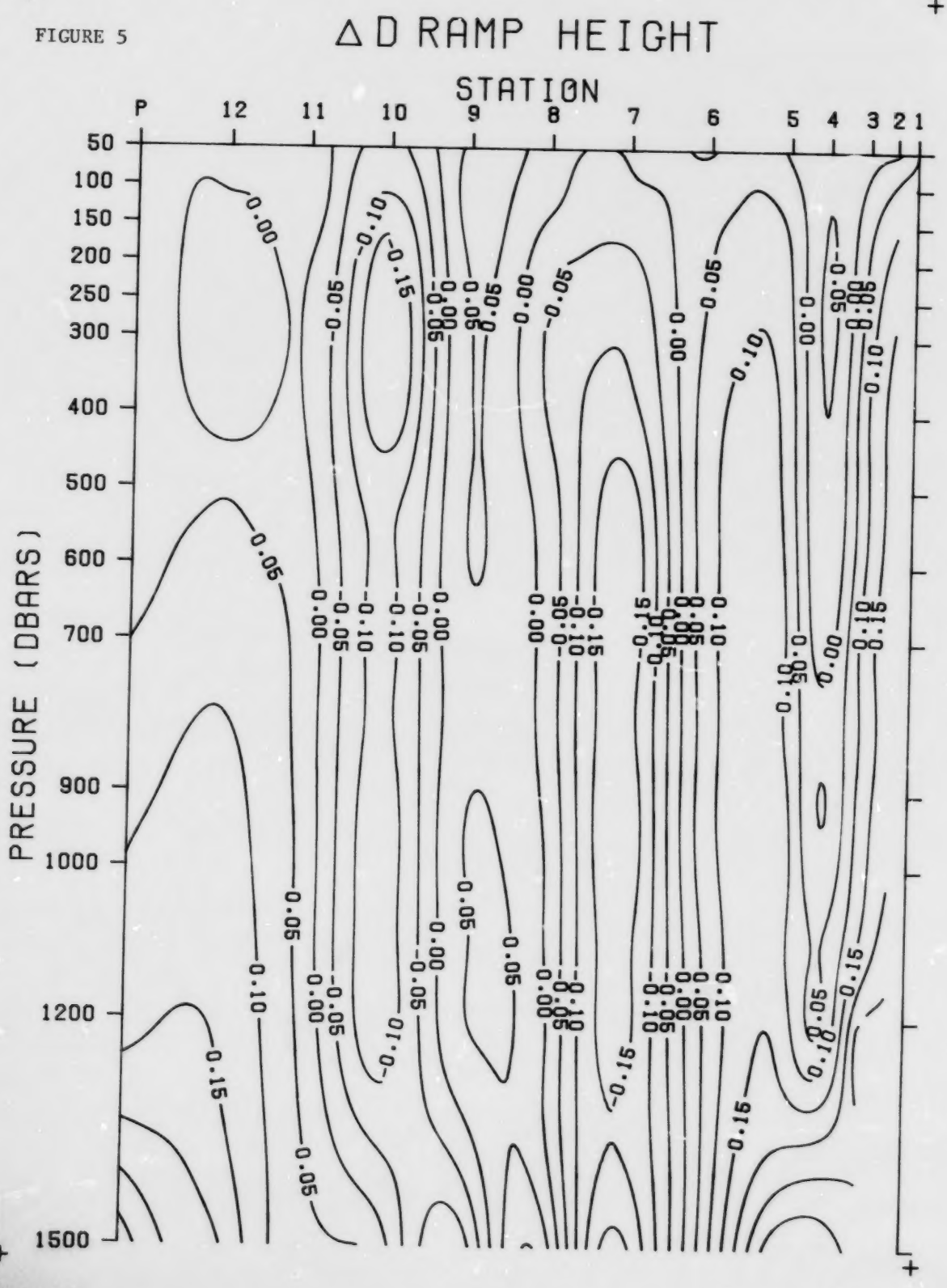

ΔD RAMP HEIGHT
STATION
P 12 11 10 9 8 7 6 5 4 3 2 1
PRESSURE (DBARS)
50
100
150
200
250
300
400
500
600
700
900
1000
1200
1500

FIGURE 6

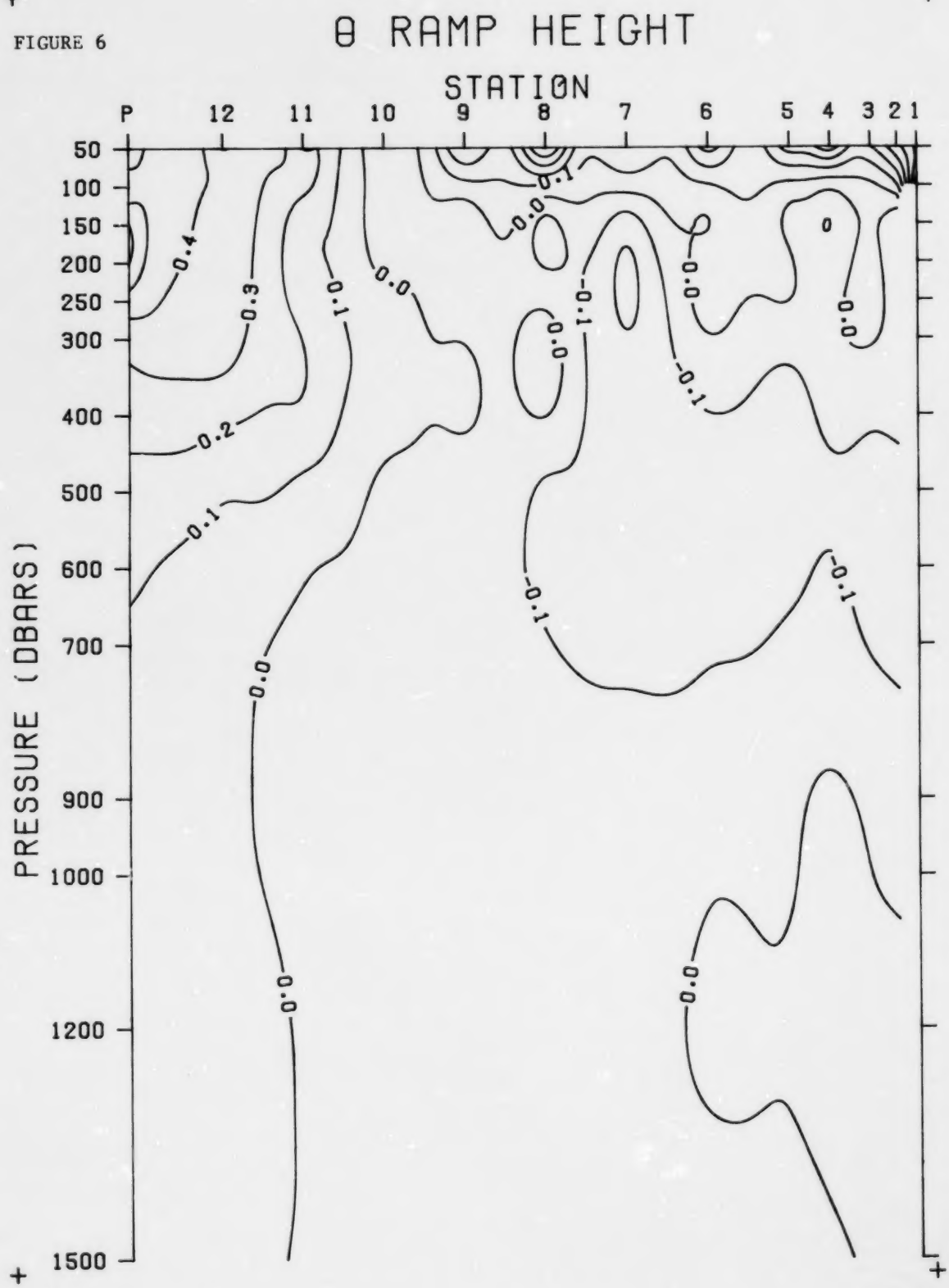

θ RAMP HEIGHT
STATION
P 12 11 10 9 8 7 6 5 4 3 2 1
PRESSURE (DBARS)
50 100 150 200 250 300 400 500 600 700 900 1000 1200 1500
0.4 0.3 0.2 0.1 0.0 -0.1 0

FIGURE 7

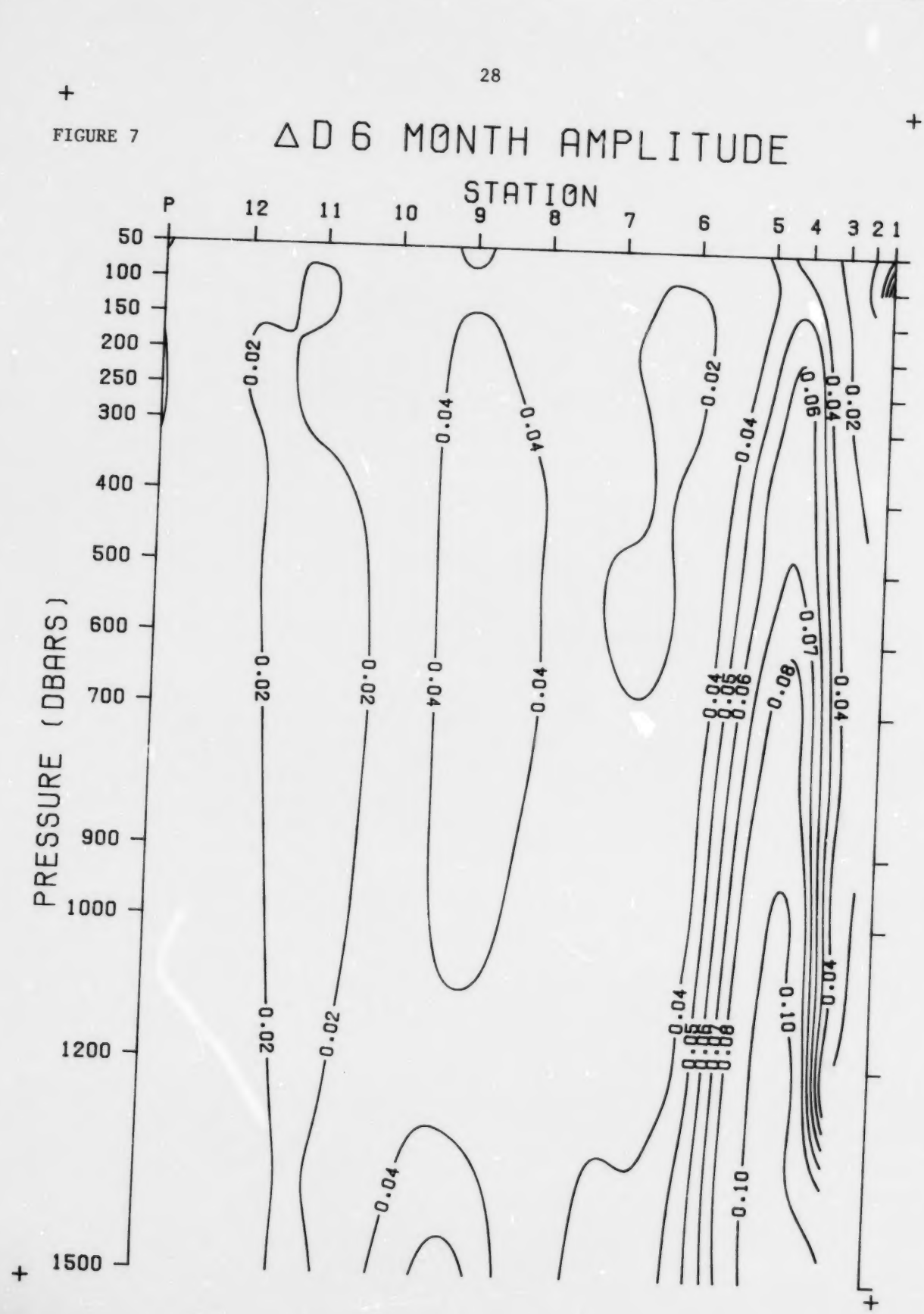

ΔD 6 MONTH AMPLITUDE
STATION
P 12 11 10 9 8 7 6 5 4 3 2 1
PRESSURE (DBARS)
50 100 150 200 250 300 400 500 600 700 900 1000 1200 1500
0.02
0.04
0.06
0.07
0.08
0.10

FIGURE 8

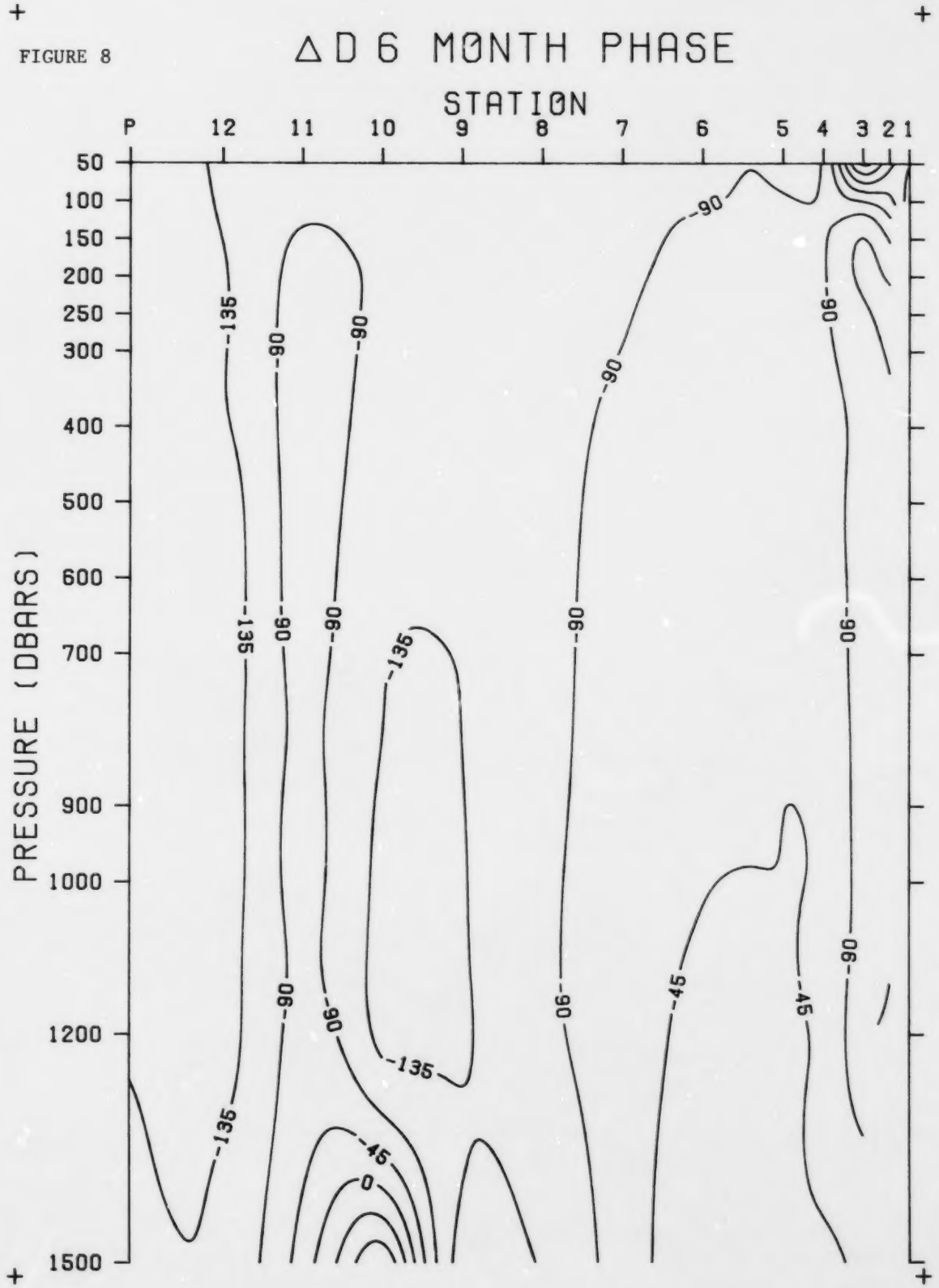

ΔD 6 MONTH PHASE
STATION
P 12 11 10 9 8 7 6 5 4 3 2 1
PRESSURE (DBARS)
50
100
150
200
250
300
400
500
600
700
900
1000
1200
1500
-135
-90
-45
0

FIGURE 9

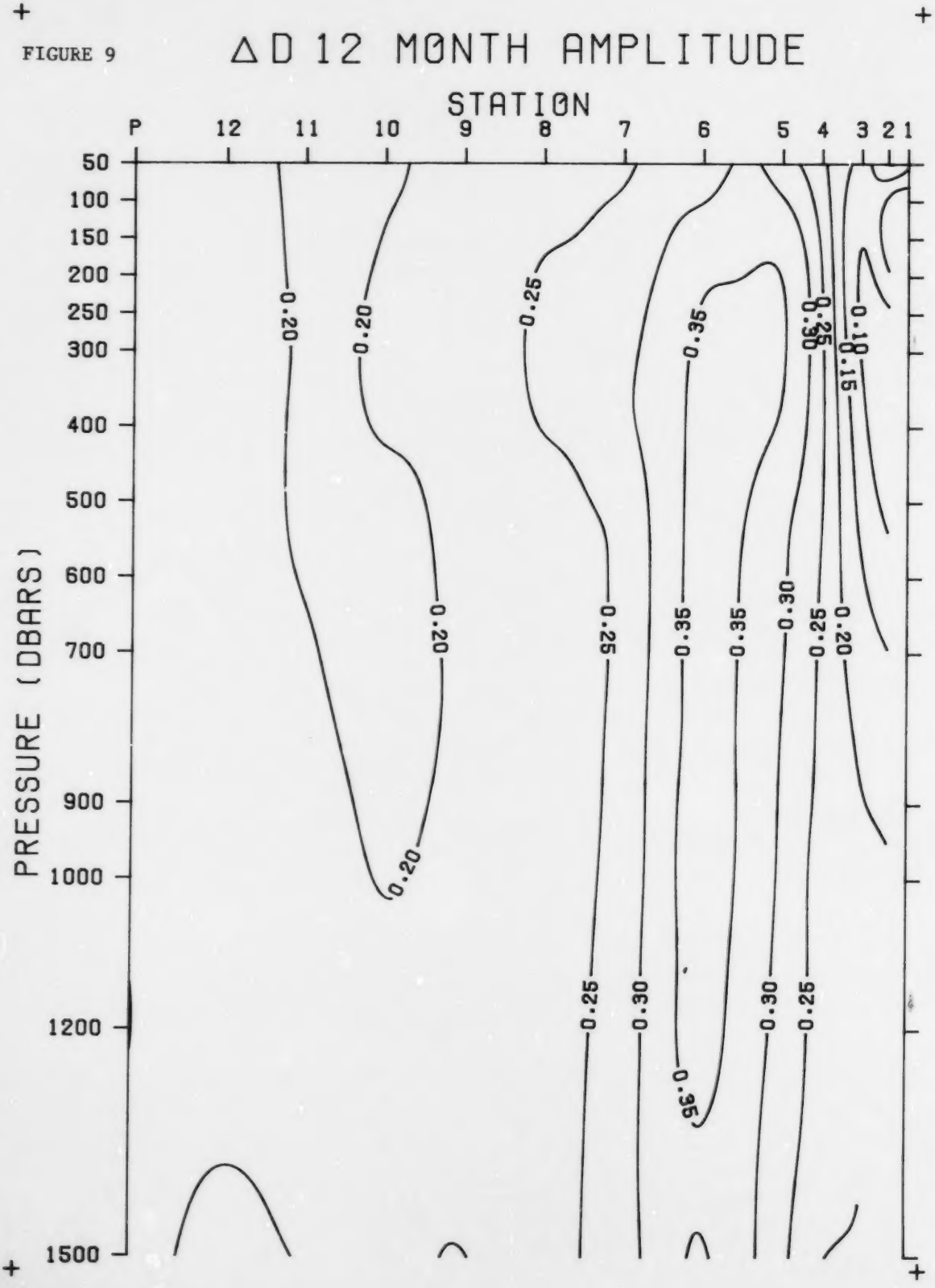

ΔD 12 MONTH AMPLITUDE
STATION
P 12 11 10 9 8 7 6 5 4 3 2 1
PRESSURE (DBARS)
50 100 150 200 250 300 400 500 600 700 900 1000 1200 1500
0.20
0.25
0.35
0.30
0.15
0.10

FIGURE 10

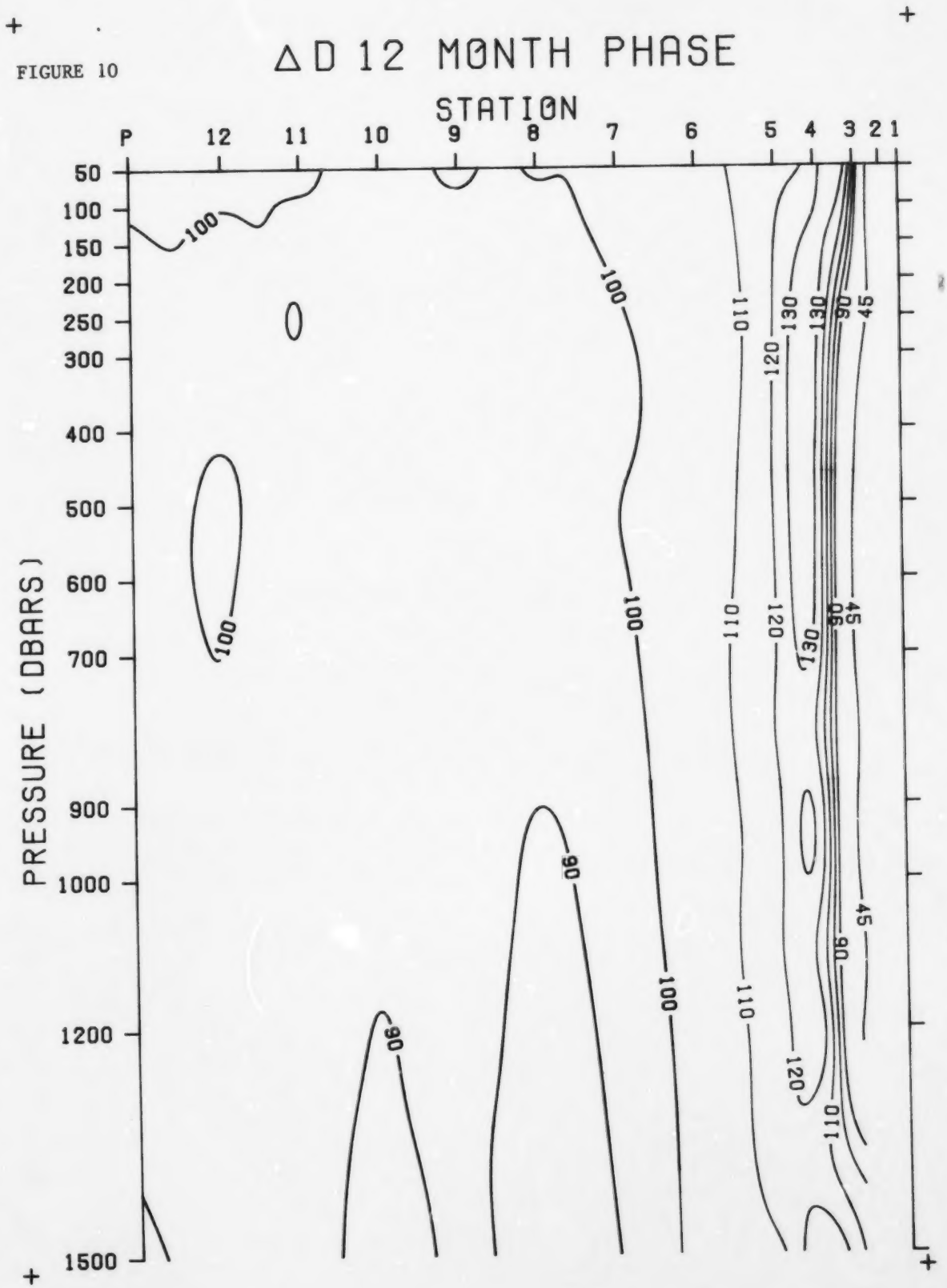

ΔD 12 MONTH PHASE
STATION
P 12 11 10 9 8 7 6 5 4 3 2 1
PRESSURE (DBARS)
50
100
150
200
250
300
400
500
600
700
900
1000
1200
1500
100
90
110
120
130
45

FIGURE 11

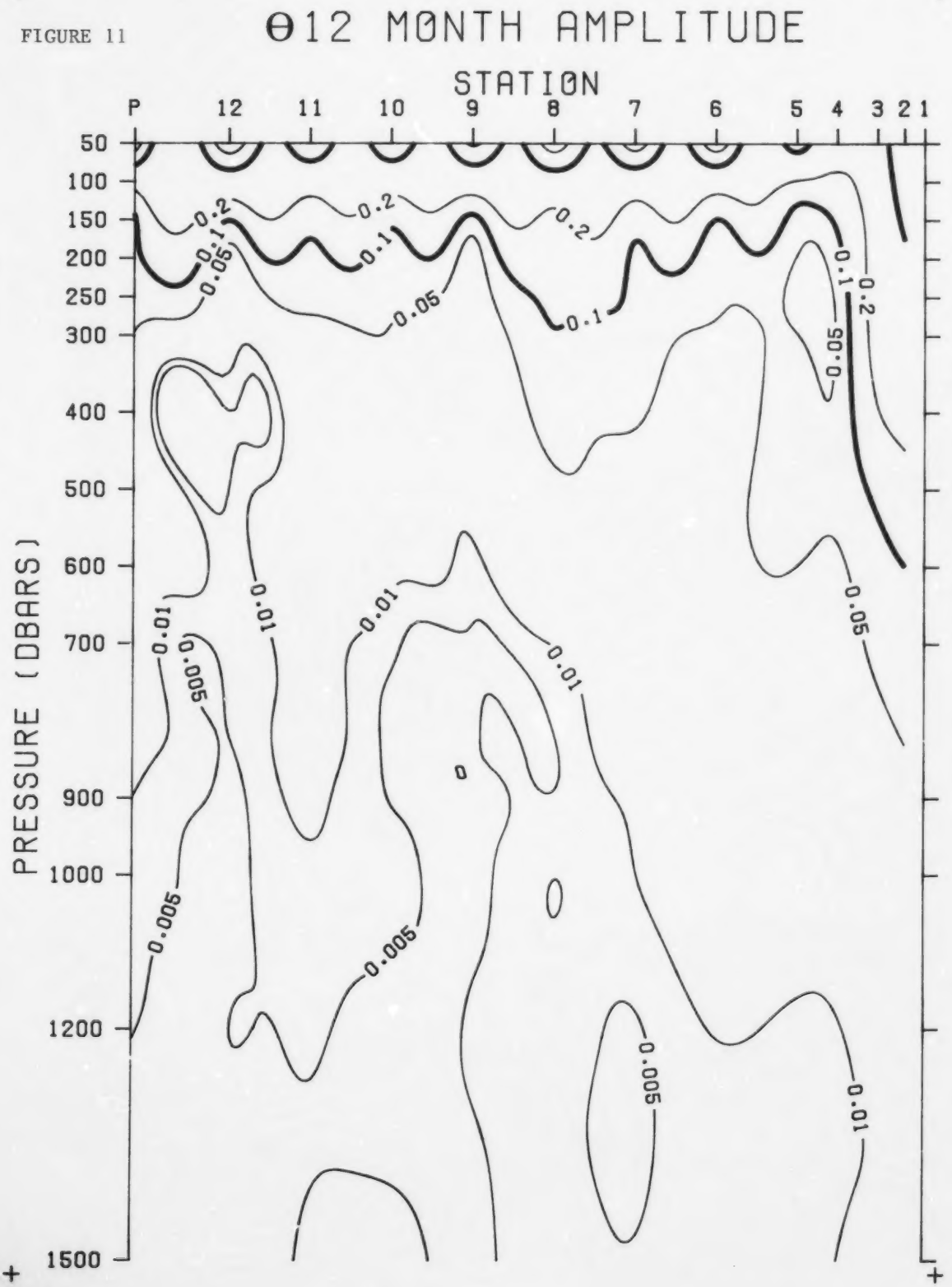
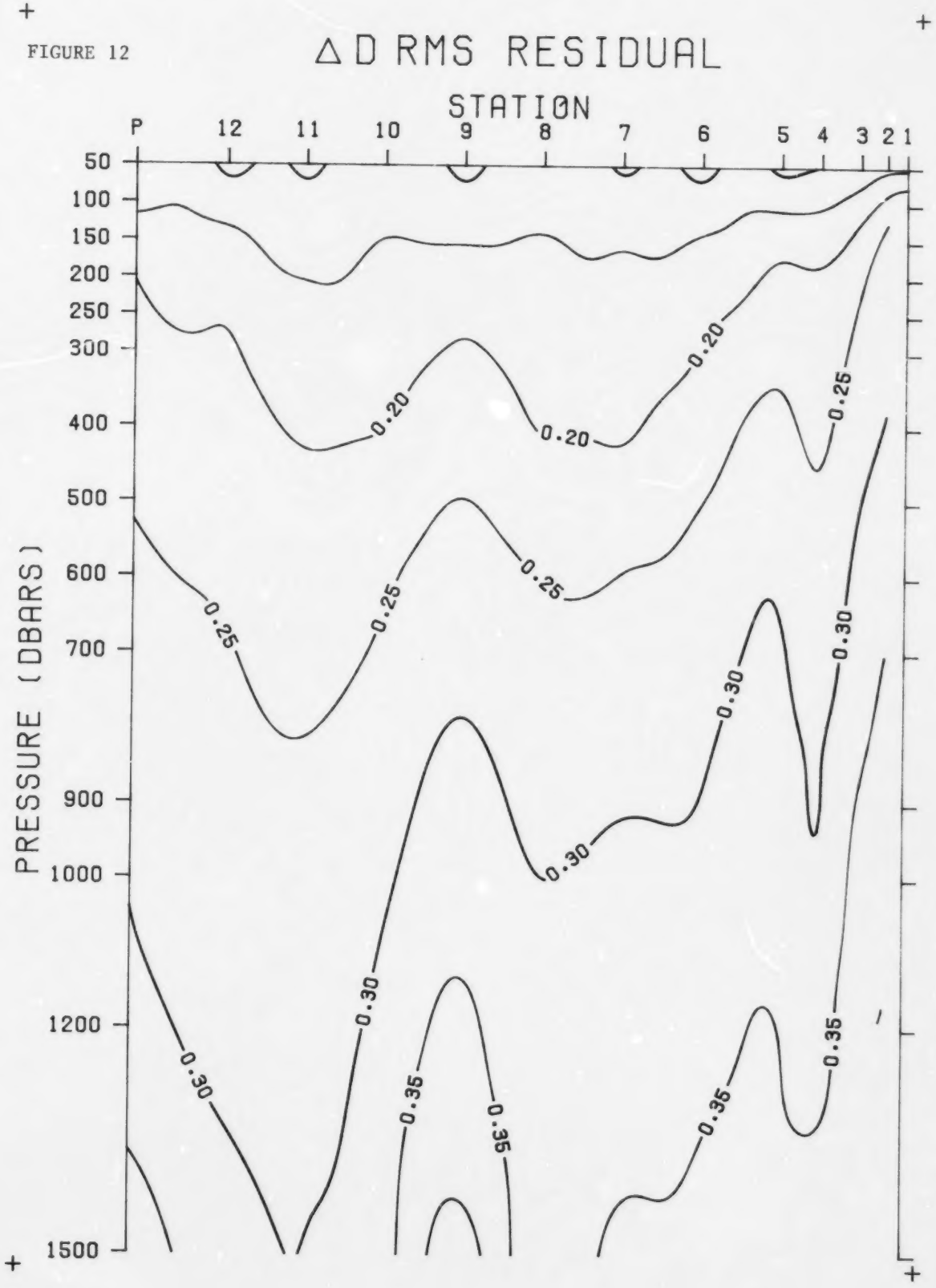

θ12 MONTH AMPLITUDE
STATION
P 12 11 10 9 8 7 6 5 4 3 2 1
PRESSURE (DBARS)
50
100
150
200
250
300
400
500
600
700
900
1000
1200
1500
0.2
0.1
0.05
0.01
0.005
0

FIGURE 12


ΔD RMS RESIDUAL
STATION
P 12 11 10 9 8 7 6 5 4 3 2 1
PRESSURE (DBARS)
50
100
150
200
250
300
400
500
600
700
900
1000
1200
1500
0.20
0.25
0.30
0.35

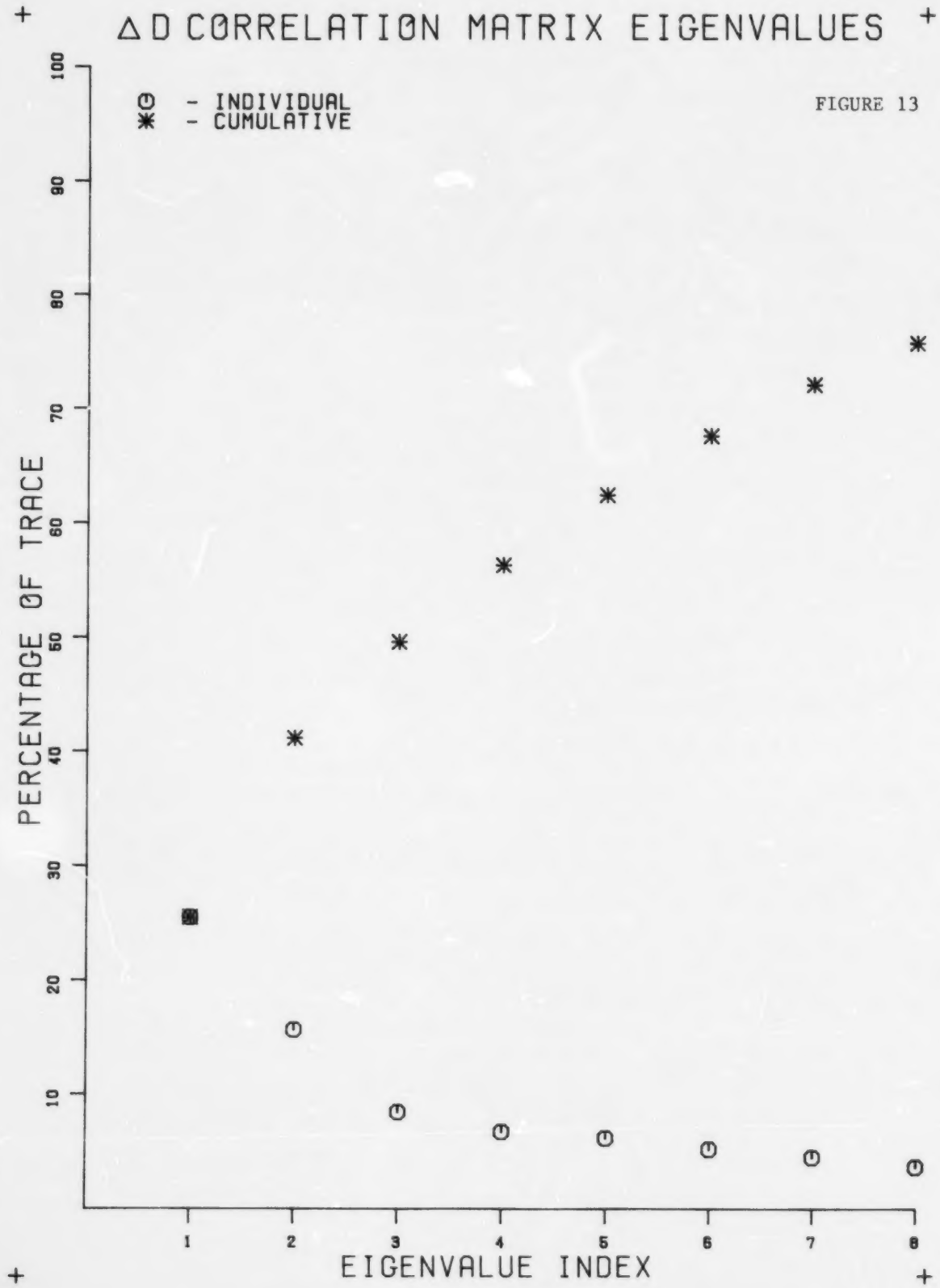

ΔD CORRELATION MATRIX EIGENVALUES
- INDIVIDUAL
- CUMULATIVE
PERCENTAGE OF TRACE
10
20
30
40
50
60
70
80
90
100
1
2
3
4
5
6
7
8
EIGENVALUE INDEX

FIGURE 13

FIGURE 14

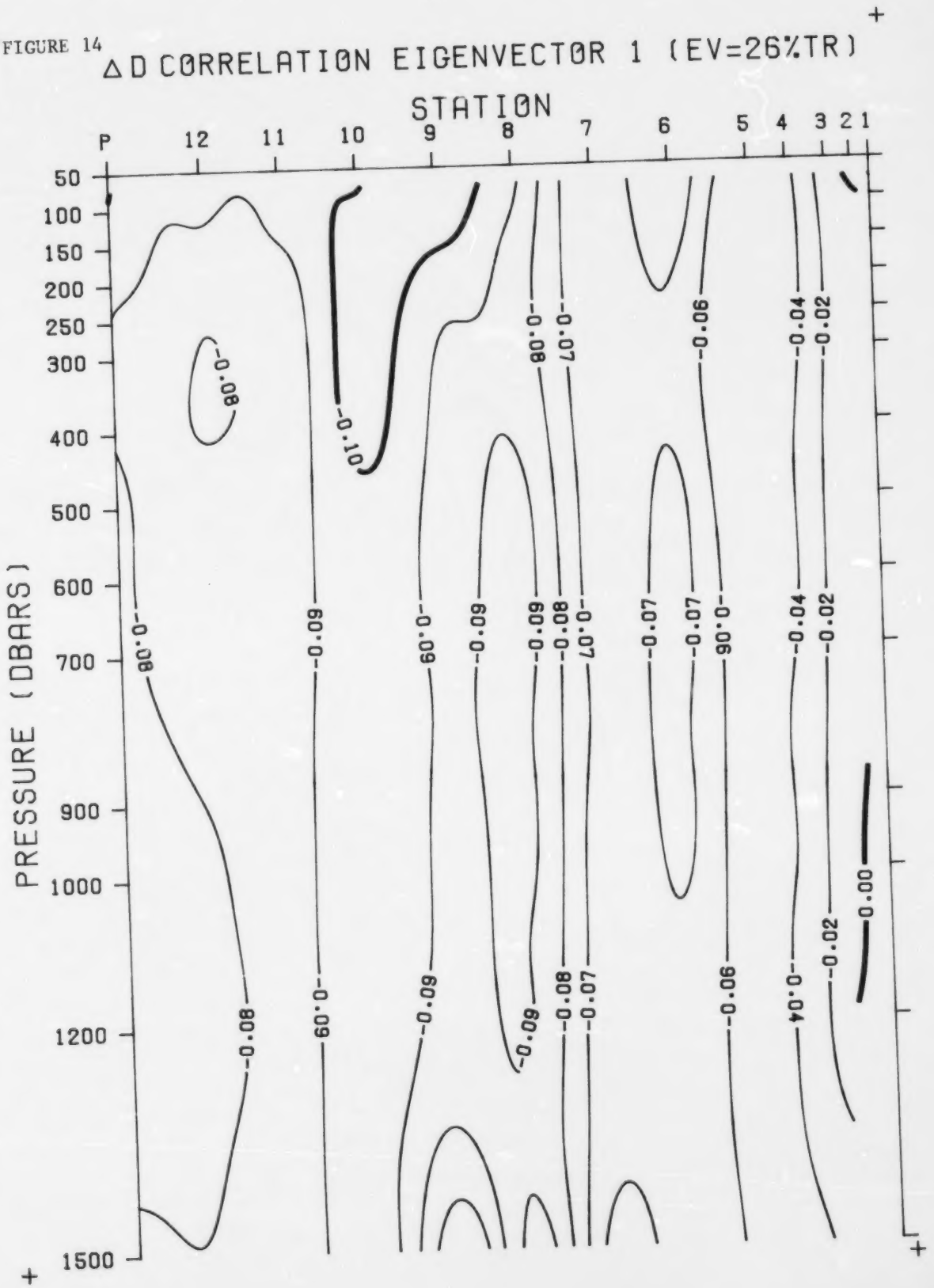

ΔD CORRELATION EIGENVECTOR 1 (EV=26%TR)
STATION
P 12 11 10 9 8 7 6 5 4 3 2 1
PRESSURE (DBARS)
50 100 150 200 250 300 400 500 600 700 900 1000 1200 1500
-0.08
-0.10
-0.09
-0.07
-0.06
-0.04
-0.02
0.00

FIGURE 15

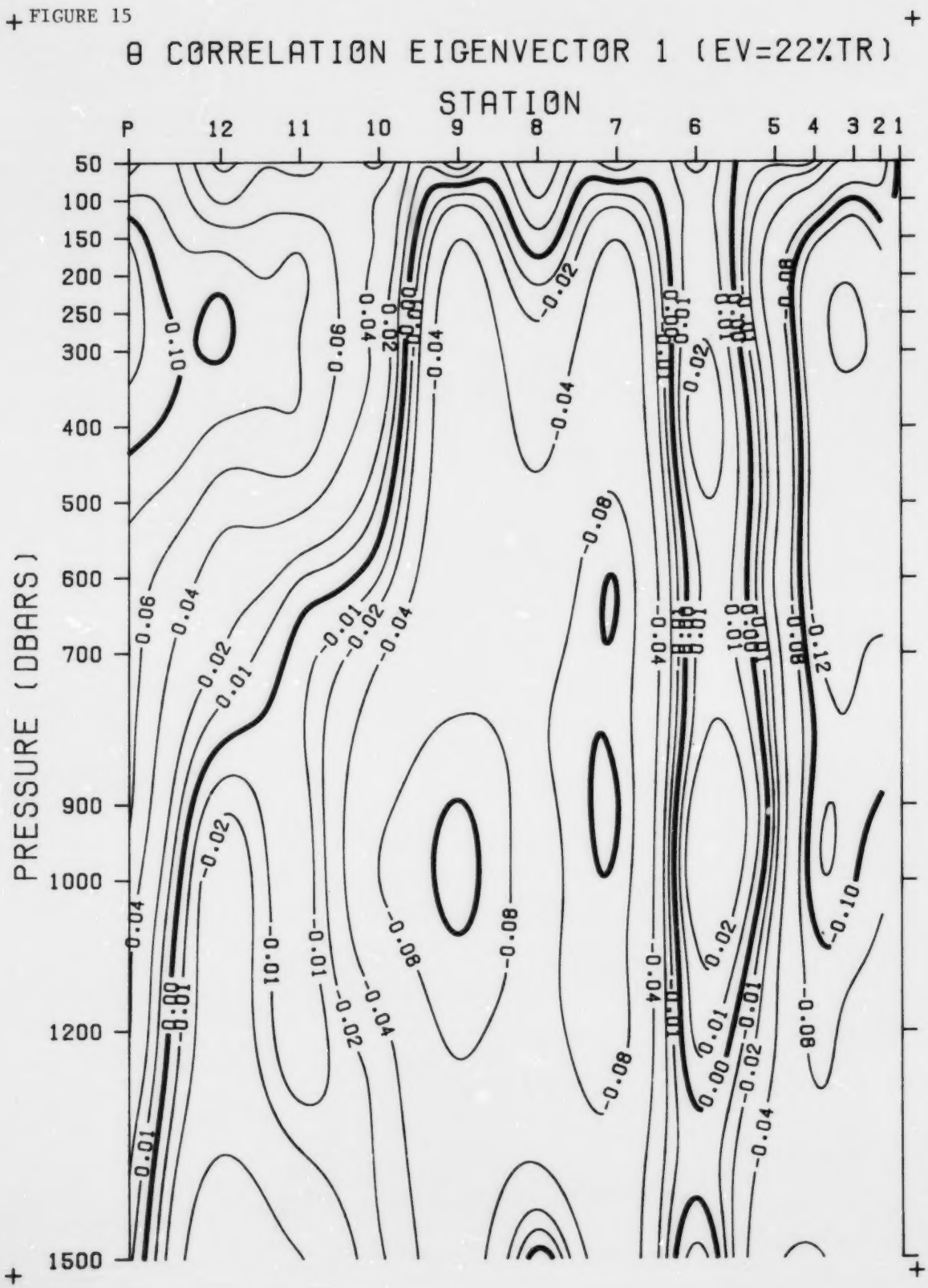
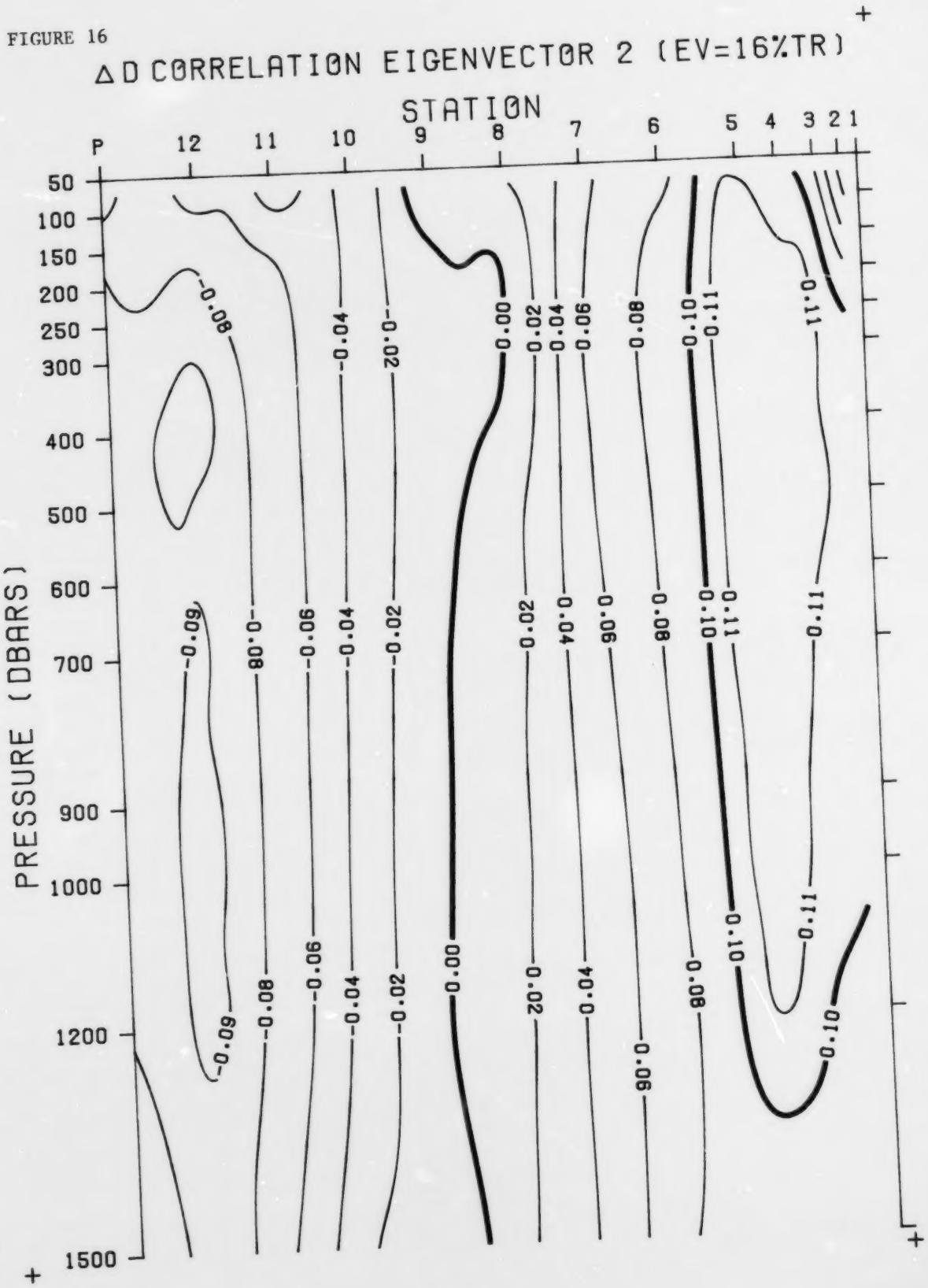
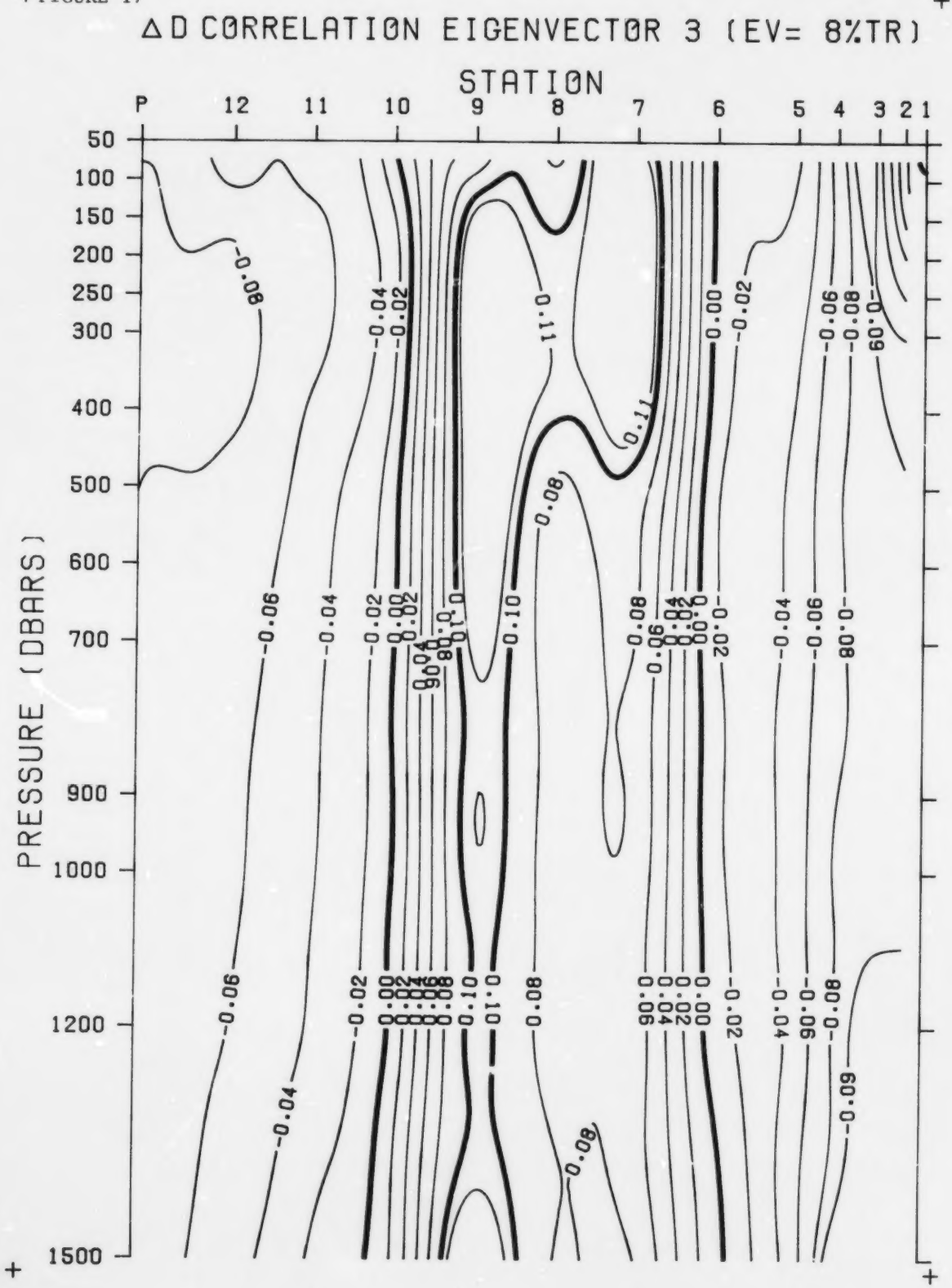

θ CORRELATION EIGENVECTOR 1 (EV=22%TR)
STATION
P 12 11 10 9 8 7 6 5 4 3 2 1
PRESSURE (DBARS)
50
100
150
200
250
300
400
500
600
700
900
1000
1200
1500

FIGURE 16


ΔD CORRELATION EIGENVECTOR 2 (EV=16%TR)
STATION
P 12 11 10 9 8 7 6 5 4 3 2 1
PRESSURE (DBARS)
50 100 150 200 250 300 400 500 600 700 900 1000 1200 1500
-0.08 -0.04 -0.02 0.00 0.02 0.04 0.06 0.08 0.10 0.11
-0.09 -0.08 -0.06 -0.04 -0.02 0.00 0.02 0.04 0.06 0.08 0.10 0.11

+FIGURE 17


ΔD CORRELATION EIGENVECTOR 3 (EV= 8%TR)
STATION
P 12 11 10 9 8 7 6 5 4 3 2 1
PRESSURE (DBARS)
50
100
150
200
250
300
400
500
600
700
900
1000
1200
1500

+FIGURE 19

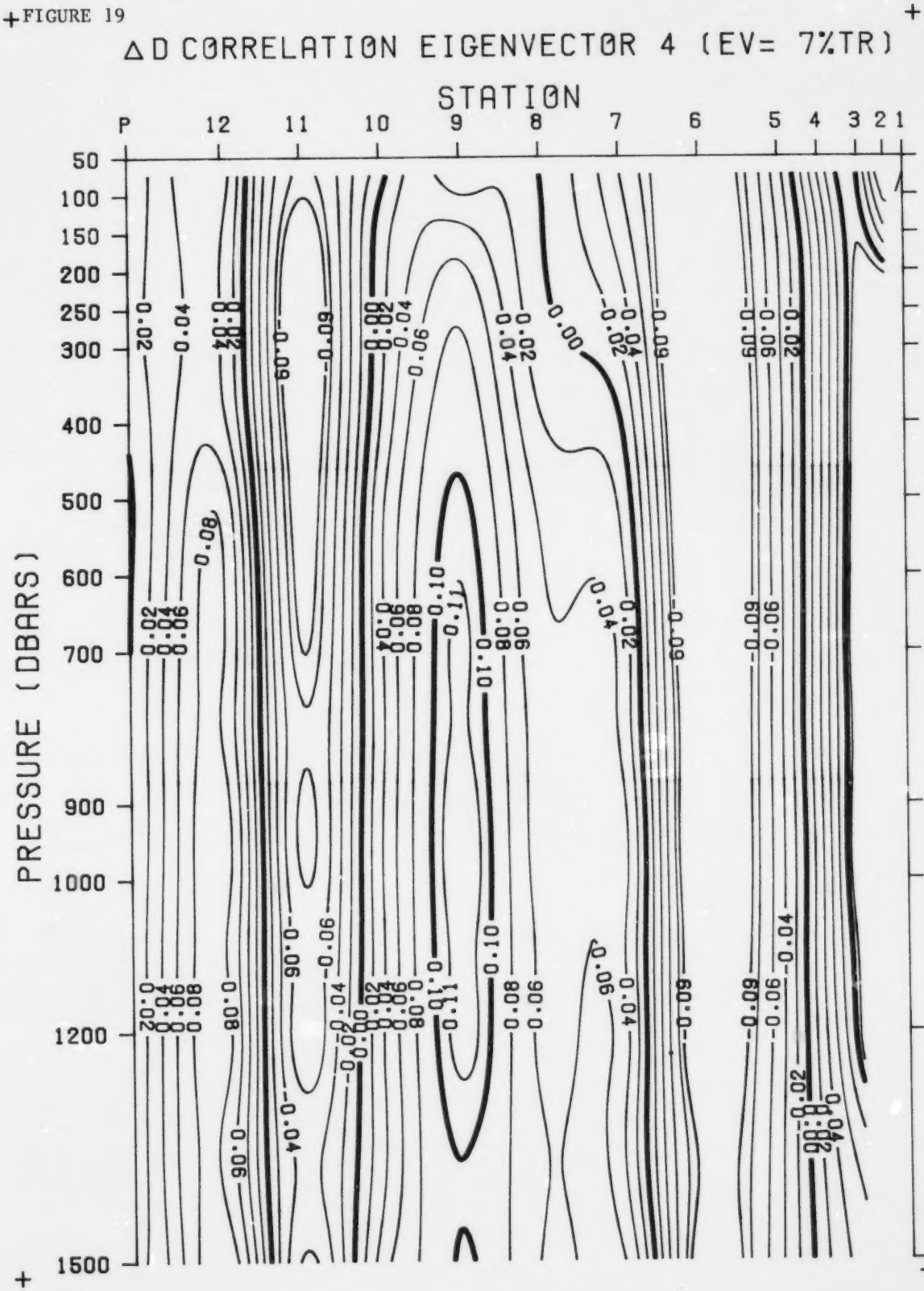

ΔD CORRELATION EIGENVECTOR 4 (EV= 7%TR)
STATION
P 12 11 10 9 8 7 6 5 4 3 2 1
PRESSURE (DBARS)
50
100
150
200
250
300
400
500
600
700
900
1000
1200
1500

FIGURE 19

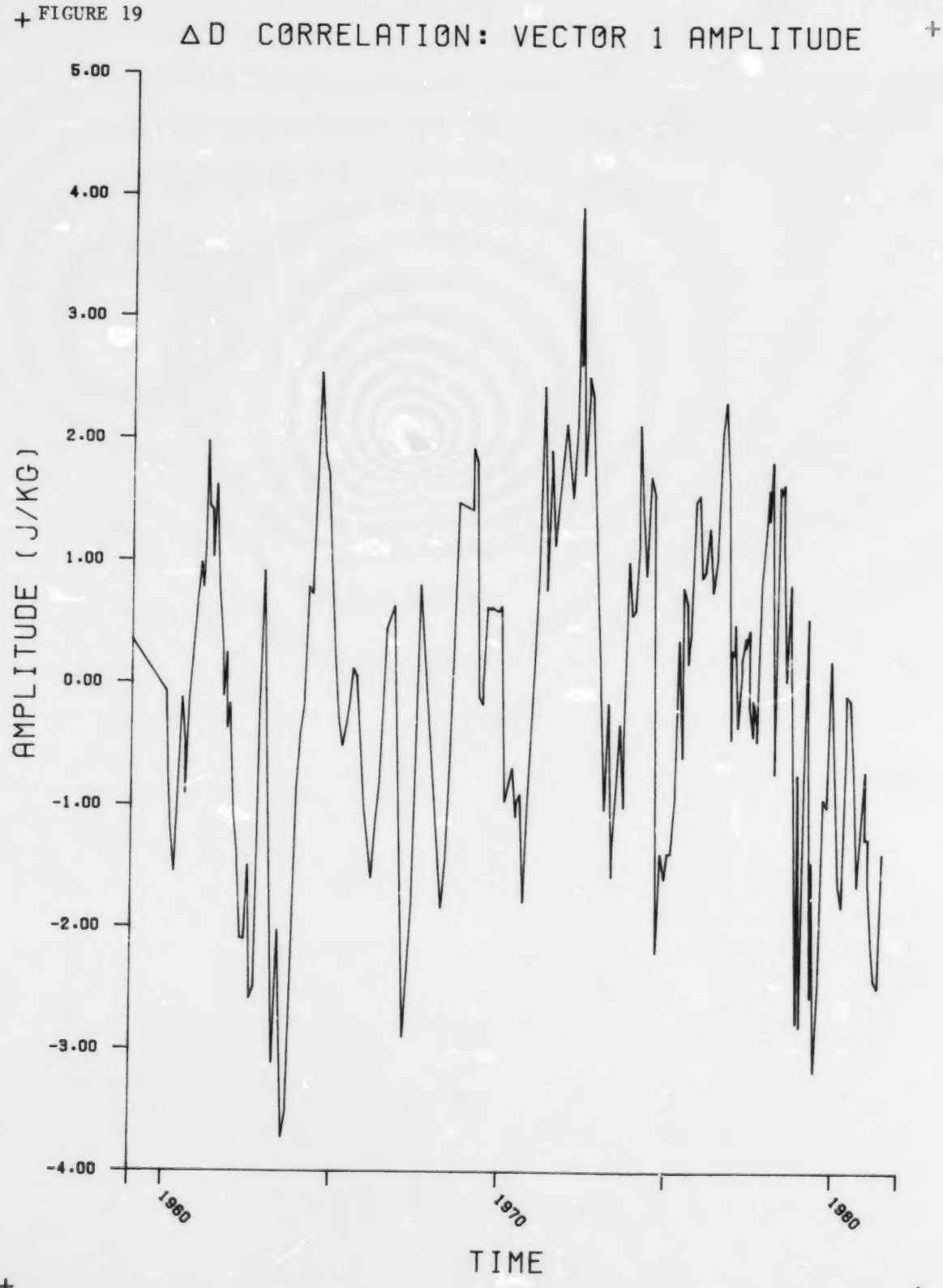

ΔD CORRELATION: VECTOR 1 AMPLITUDE
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
AMPLITUDE (J/KG)
1960
1970
1980
TIME

FIGURE 20

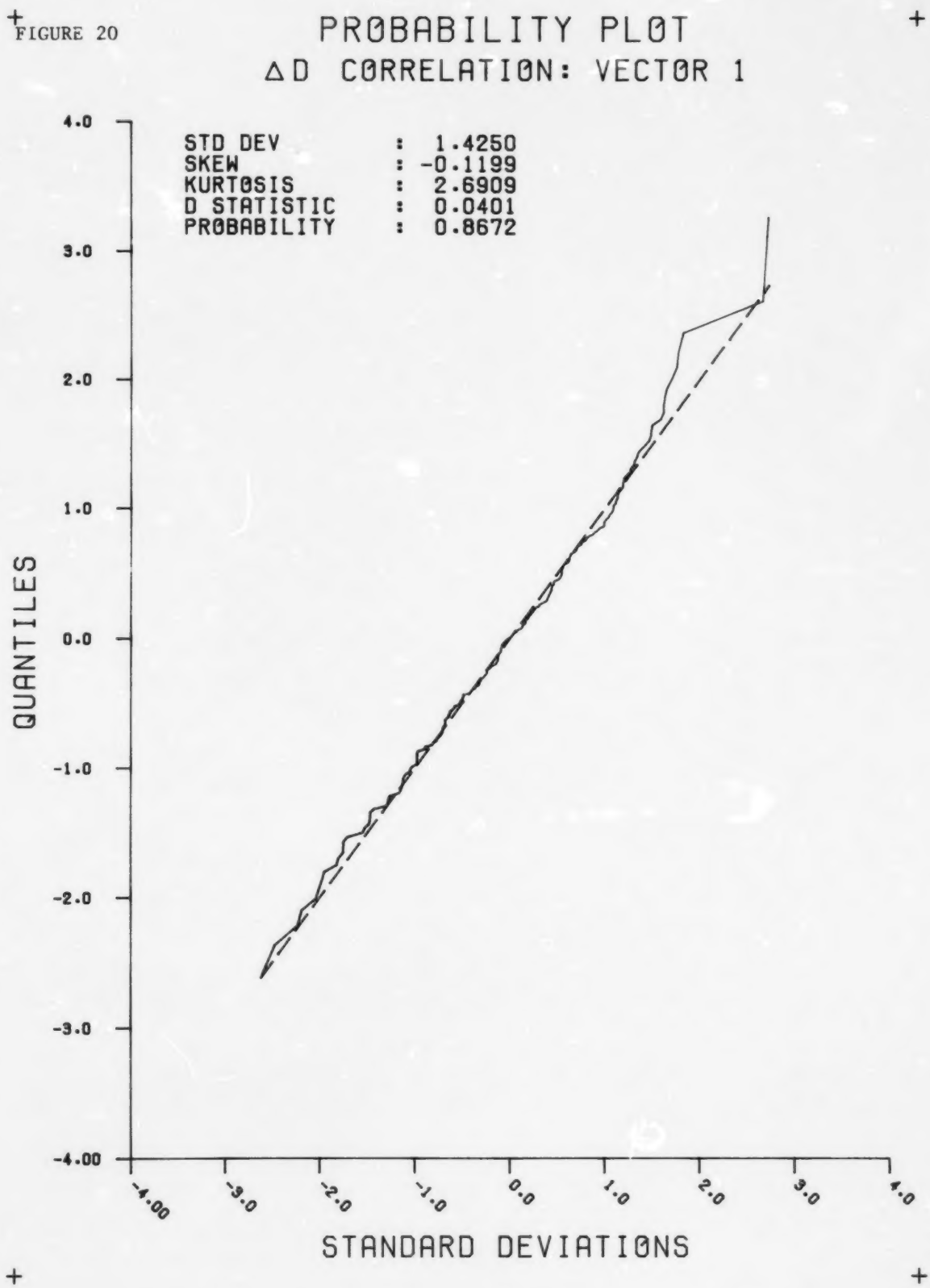

PROBABILITY PLOT
ΔD CORRELATION: VECTOR 1
STD DEV : 1.4250
SKEW : -0.1199
KURTOSIS : 2.6909
D STATISTIC : 0.0401
PROBABILITY : 0.8672
QUANTILES
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.00
-4.00
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
STANDARD DEVIATIONS

FIGURE 21

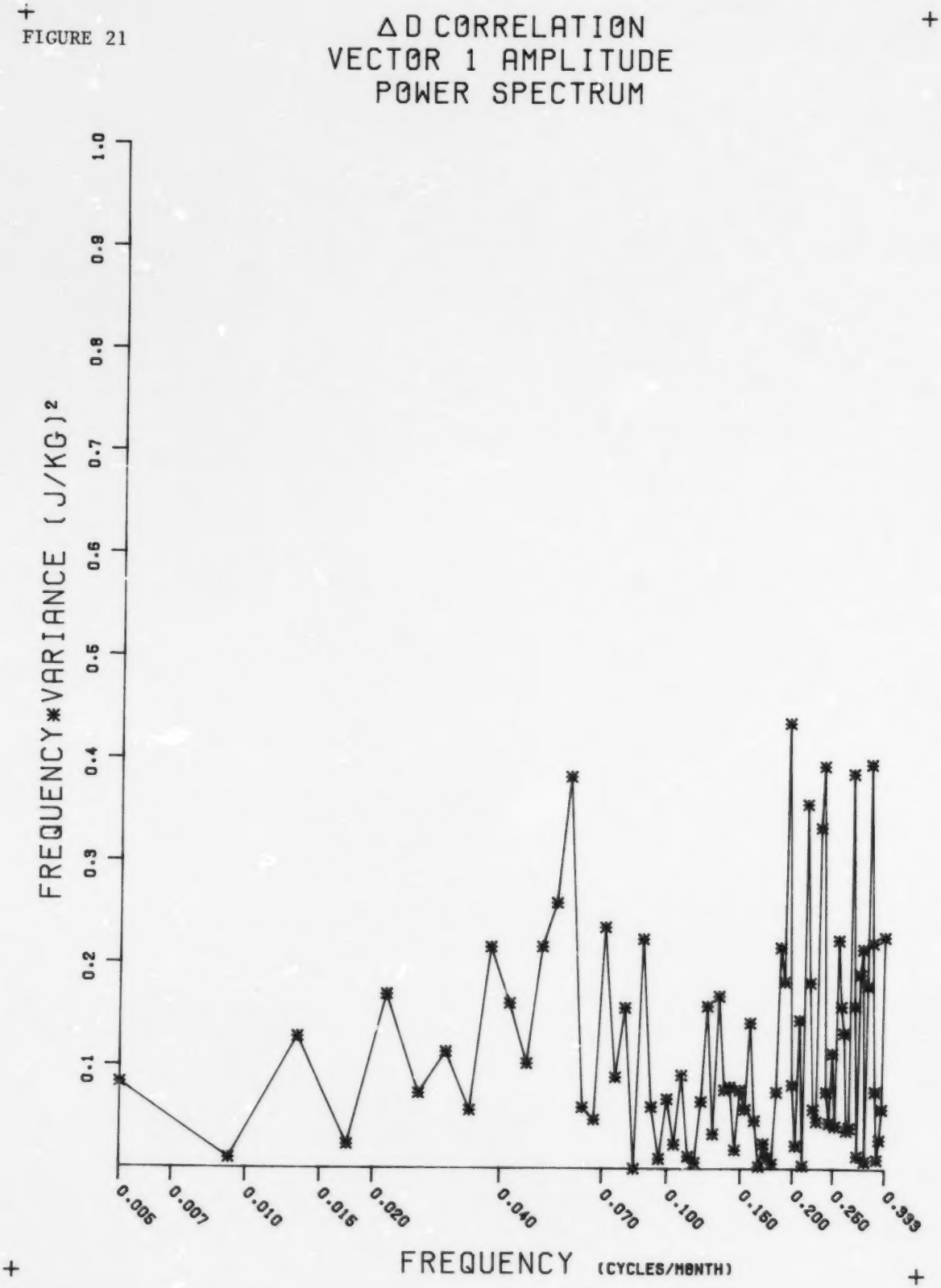

ΔD CORRELATION
VECTOR 1 AMPLITUDE
POWER SPECTRUM
FREQUENCY*VARIANCE (J/KG)²
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.005
0.007
0.010
0.015
0.020
0.040
0.070
0.100
0.150
0.200
0.250
0.333
FREQUENCY (CYCLES/MONTH)

FIGURE 22

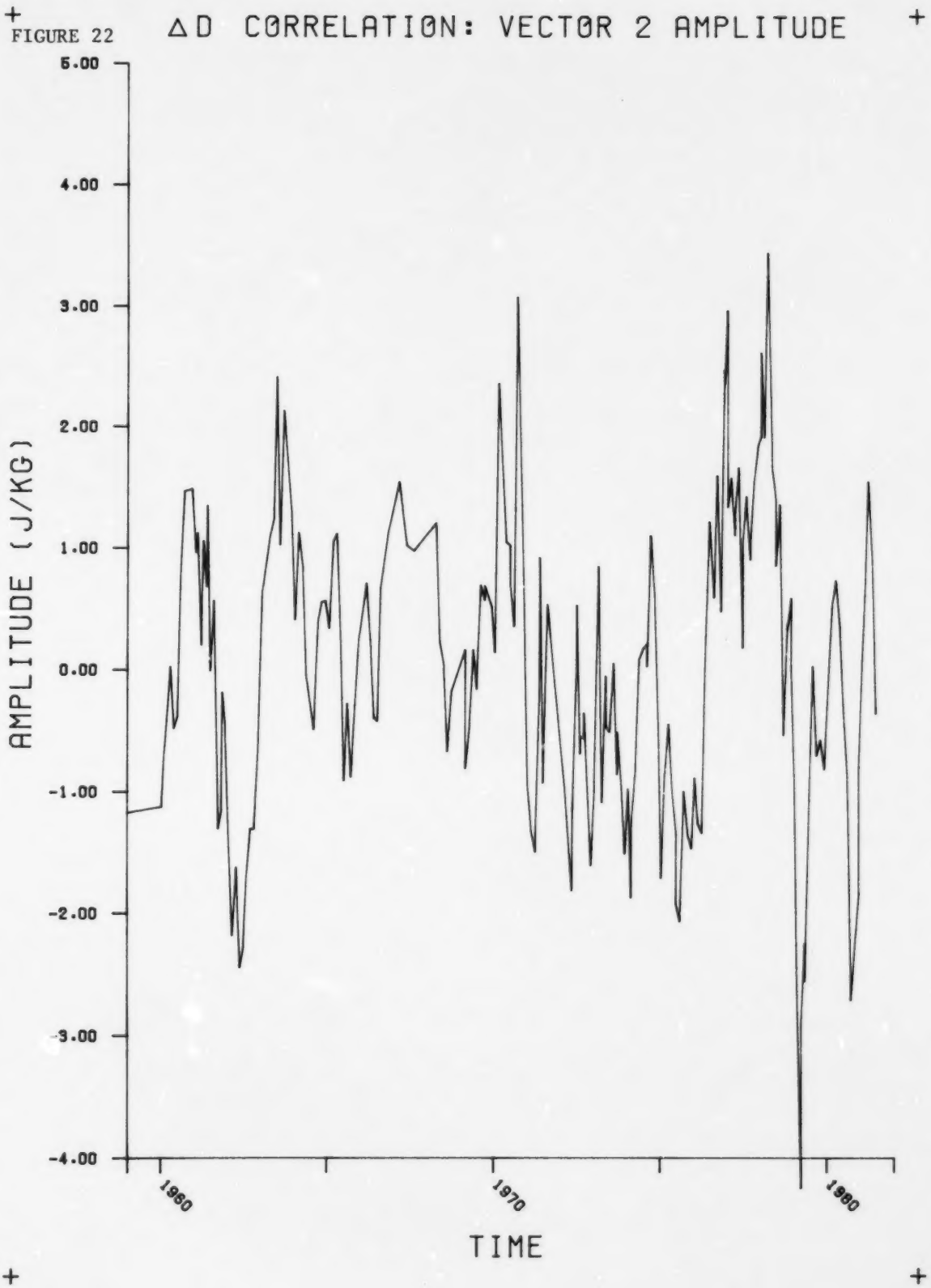

ΔD CORRELATION: VECTOR 2 AMPLITUDE
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
AMPLITUDE (J/KG)
1960
1970
1980
TIME

FIGURE 23

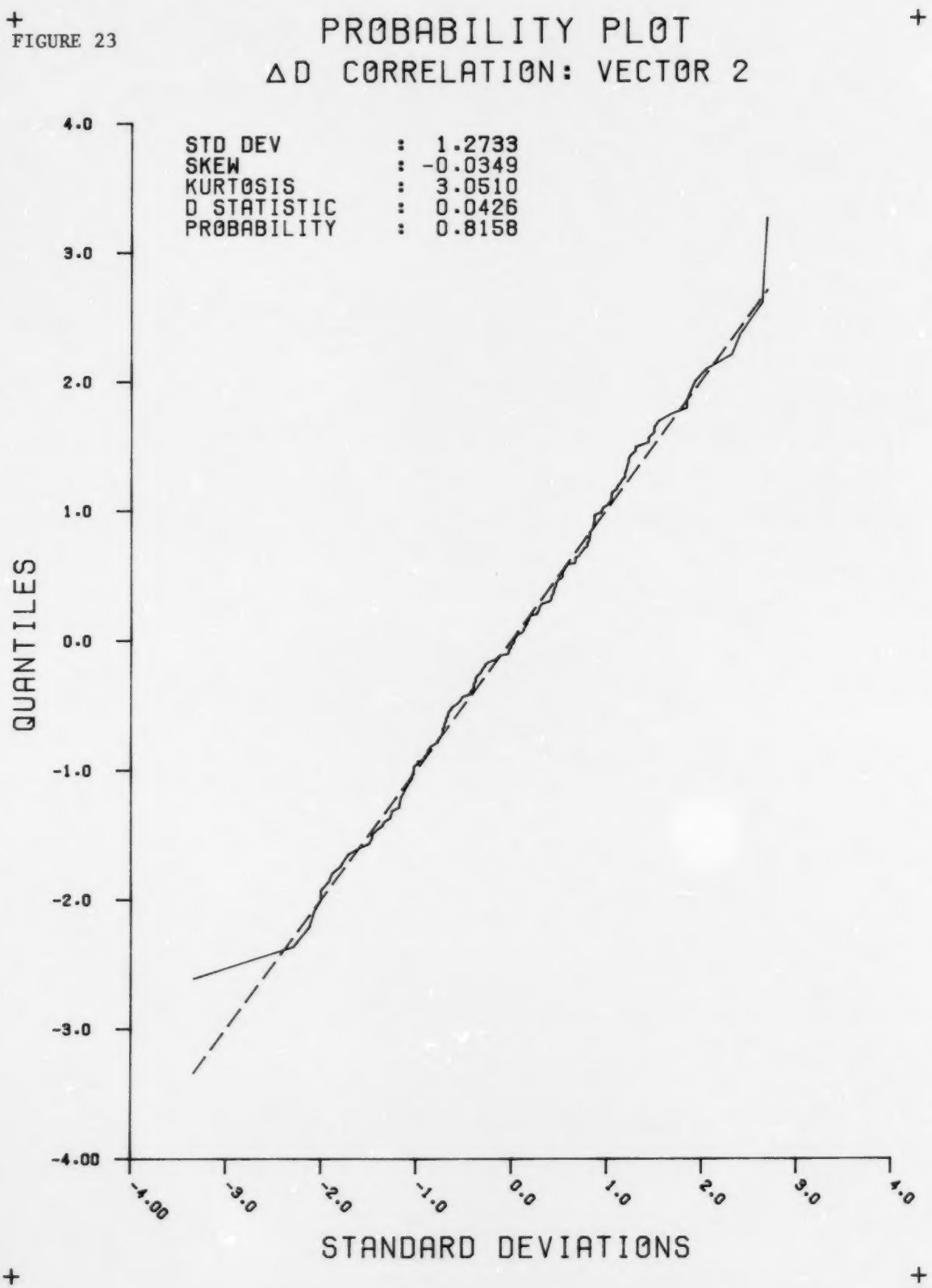

PROBABILITY PLOT
ΔD CORRELATION: VECTOR 2
STD DEV : 1.2733
SKEW : -0.0349
KURTOSIS : 3.0510
D STATISTIC : 0.0426
PROBABILITY : 0.8158
QUANTILES
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.00
-4.00
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
STANDARD DEVIATIONS

FIGURE 24

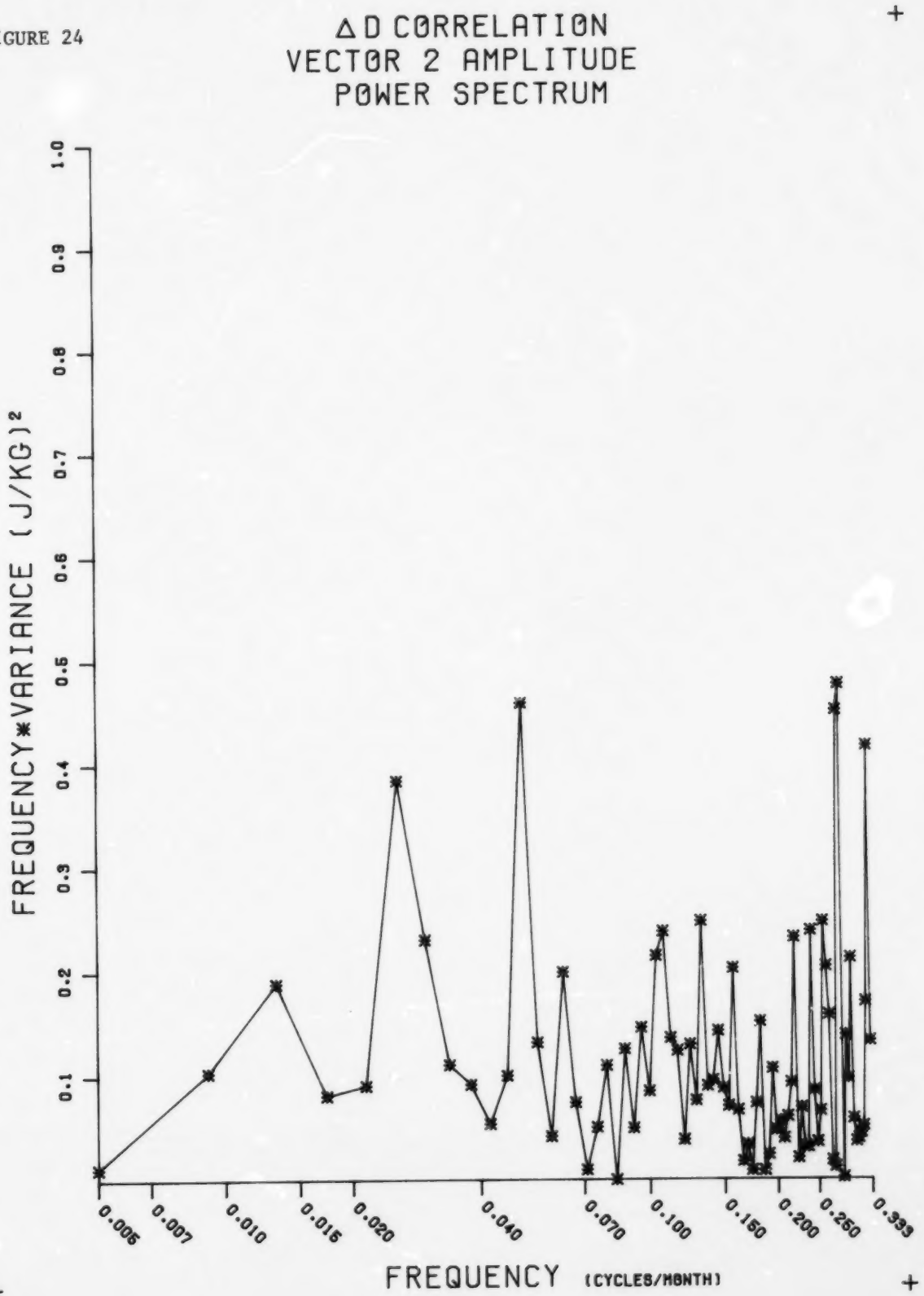

ΔD CORRELATION
VECTOR 2 AMPLITUDE
POWER SPECTRUM
FREQUENCY*VARIANCE (J/KG)²
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.005
0.007
0.010
0.015
0.020
0.040
0.070
0.100
0.150
0.200
0.250
0.333
FREQUENCY (CYCLES/MONTH)

FIGURE 25 ΔD CORRELATION: VECTOR 3 AMPLITUDE

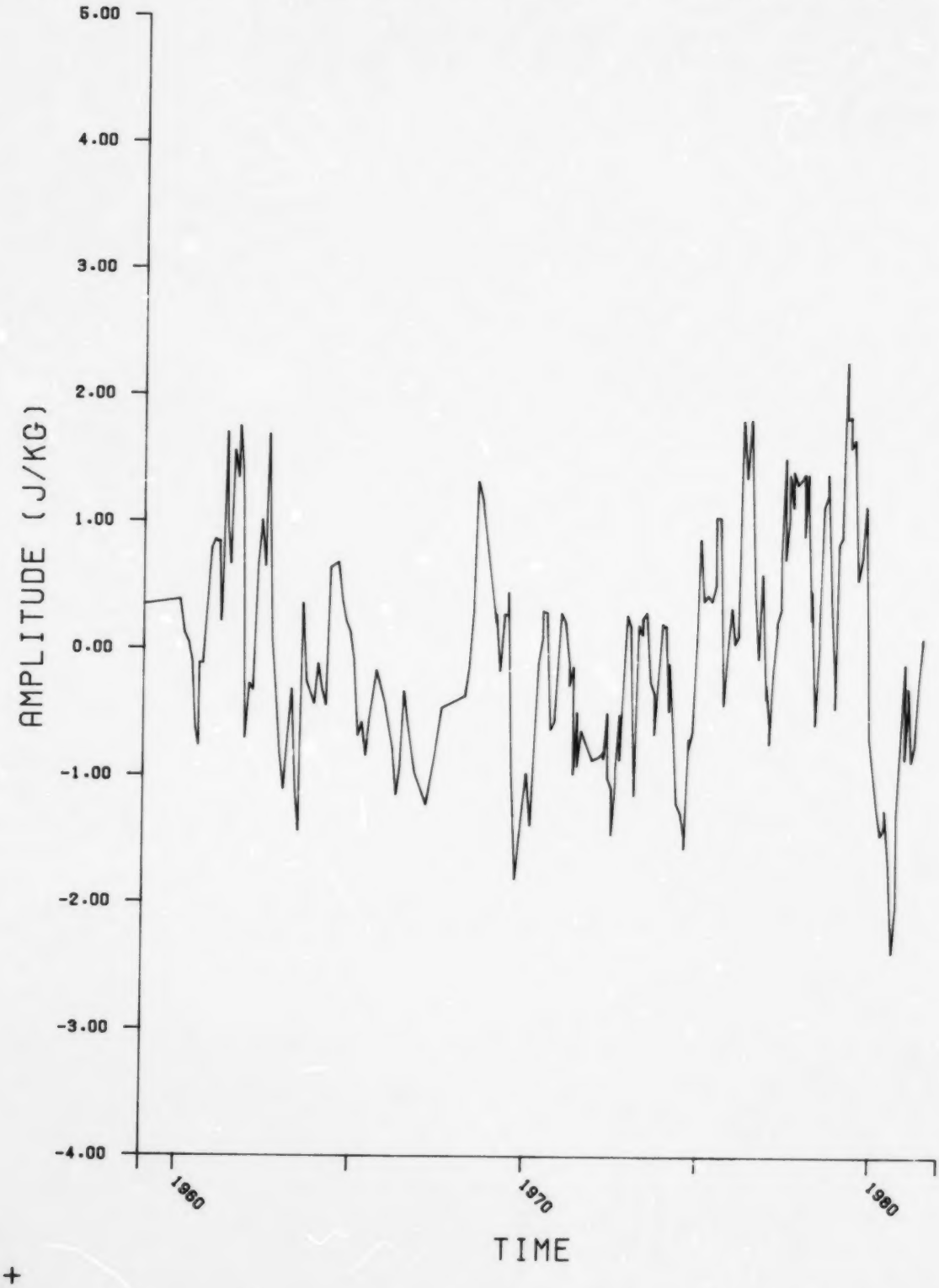


FIGURE 26

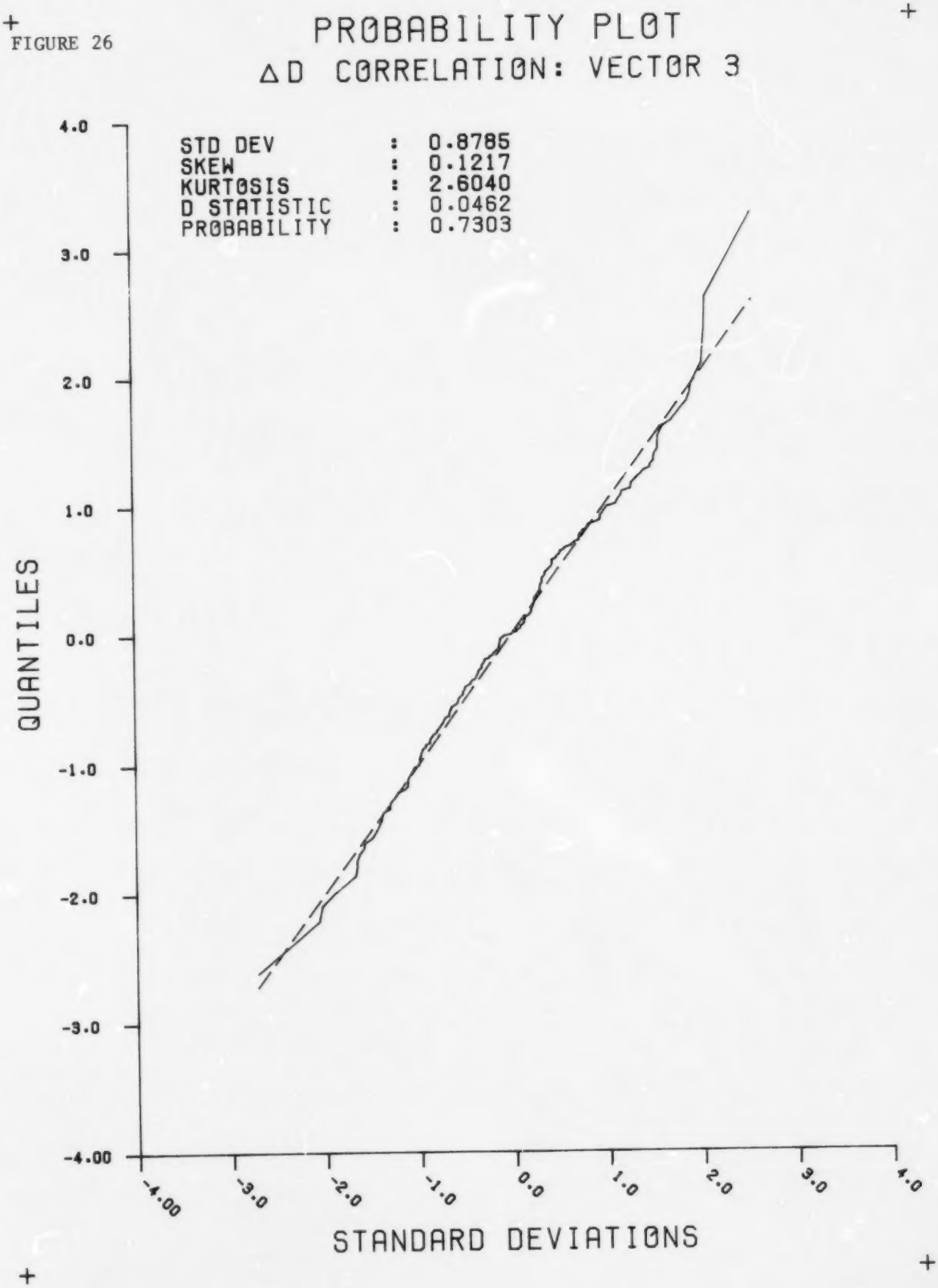

PROBABILITY PLOT
ΔD CORRELATION: VECTOR 3
STD DEV : 0.8785
SKEW : 0.1217
KURTOSIS : 2.6040
D STATISTIC : 0.0462
PROBABILITY : 0.7303
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.00
QUANTILES
-4.00
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
STANDARD DEVIATIONS

FIGURE 27

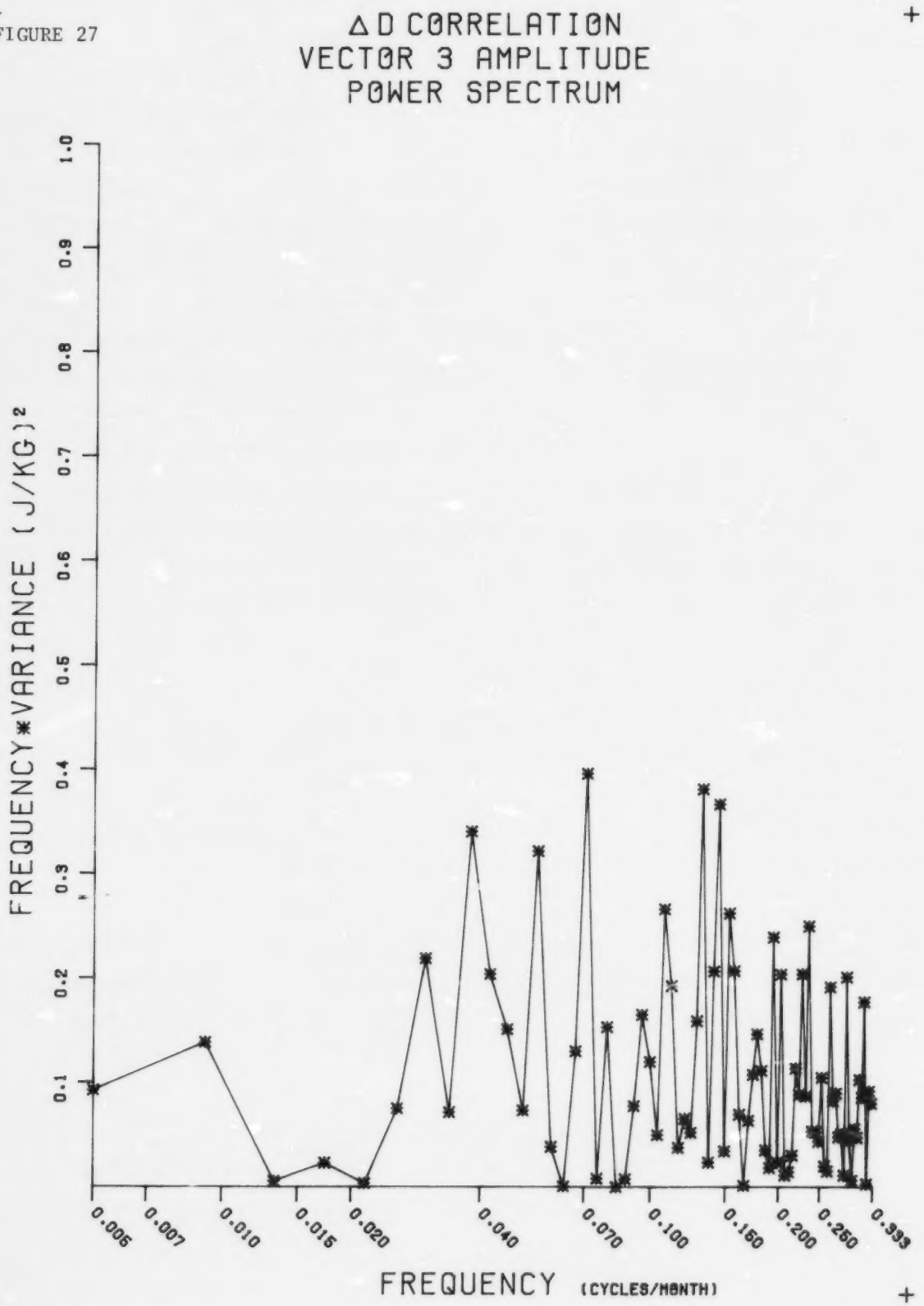

ΔD CORRELATION
VECTOR 3 AMPLITUDE
POWER SPECTRUM
FREQUENCY*VARIANCE (J/KG)²
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.005
0.007
0.010
0.015
0.020
0.040
0.070
0.100
0.150
0.200
0.250
0.333
FREQUENCY (CYCLES/MONTH)

FIGURE 28 ΔD CORRELATION: VECTOR 4 AMPLITUDE

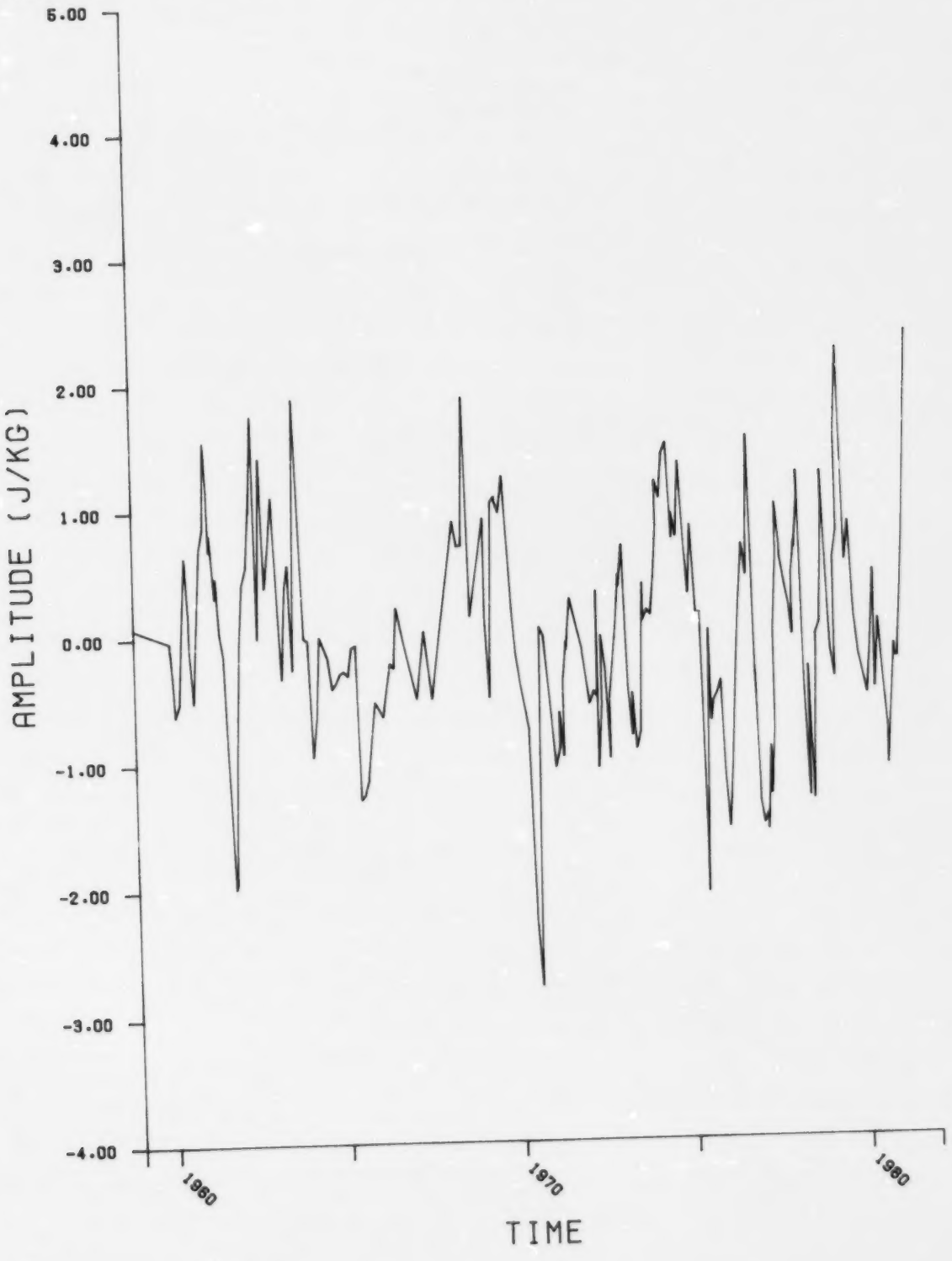


FIGURE 29

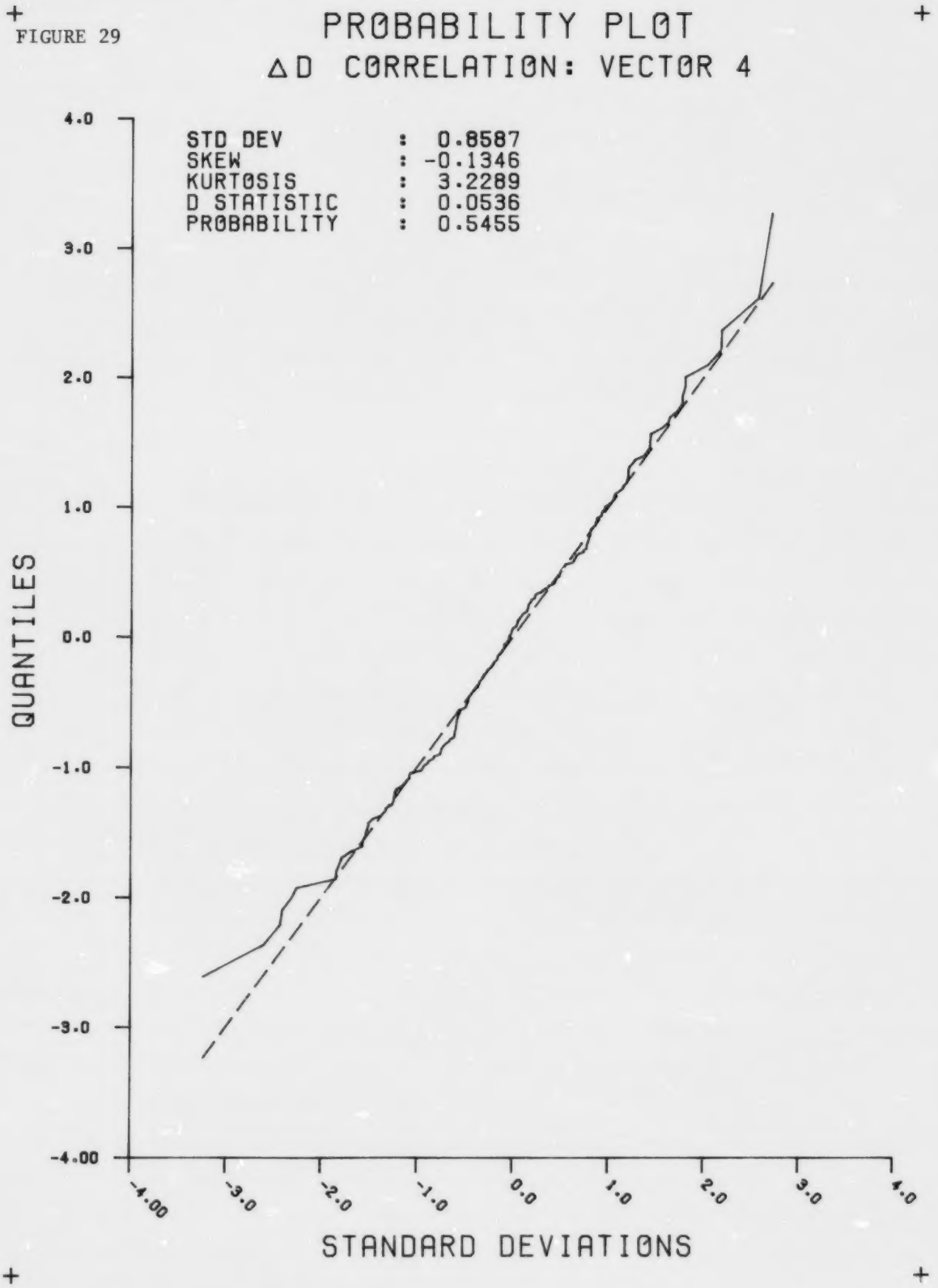

PROBABILITY PLOT
ΔD CORRELATION: VECTOR 4
STD DEV : 0.8587
SKEW : -0.1346
KURTOSIS : 3.2289
D STATISTIC : 0.0536
PROBABILITY : 0.5455
QUANTILES
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.00
-4.00
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
STANDARD DEVIATIONS

FIGURE 30

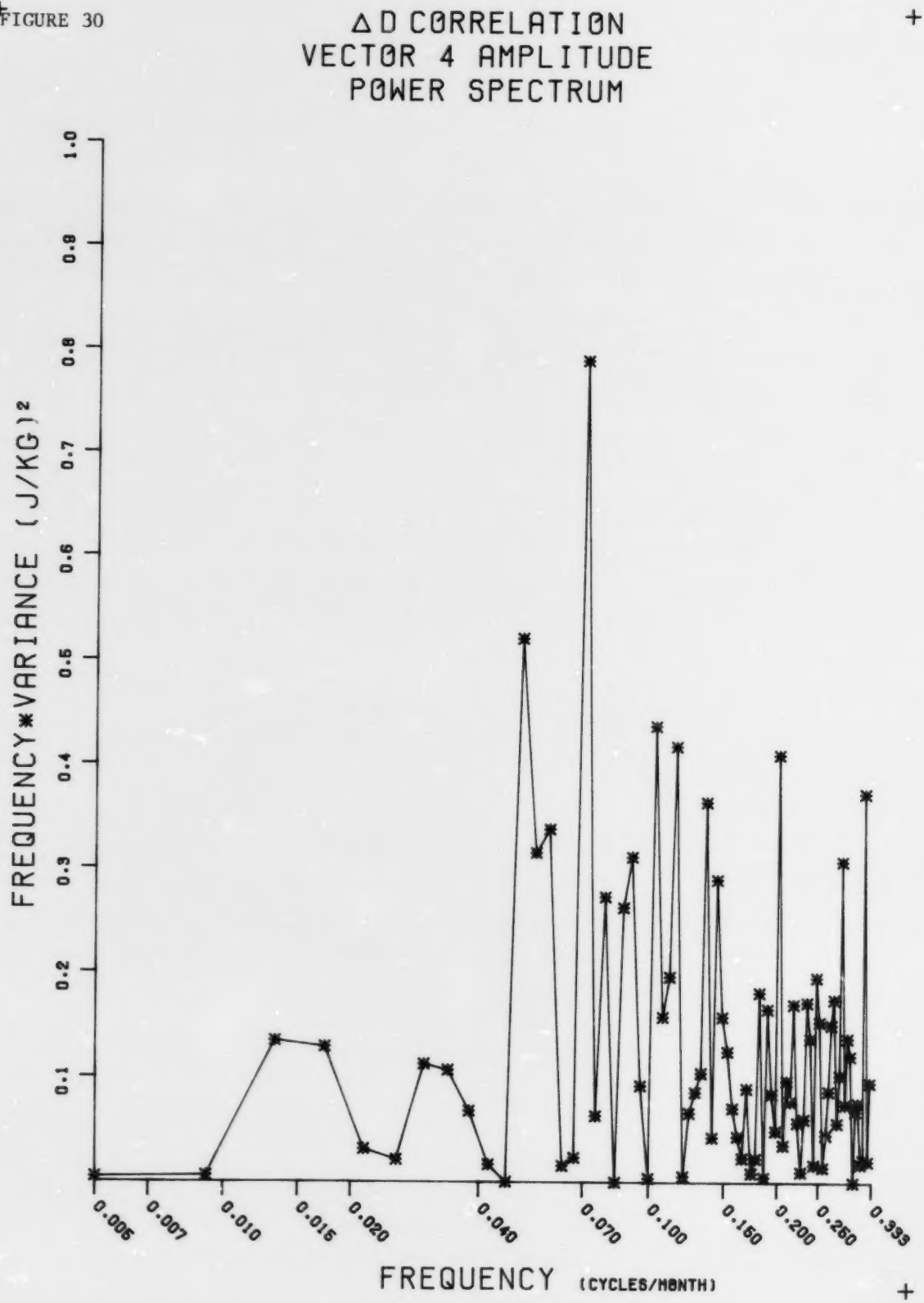

ΔD CORRELATION
VECTOR 4 AMPLITUDE
POWER SPECTRUM
FREQUENCY*VARIANCE (J/KG)²
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.006
0.007
0.010
0.015
0.020
0.040
0.070
0.100
0.150
0.200
0.250
0.333
FREQUENCY (CYCLES/MONTH)

FIGURE 31

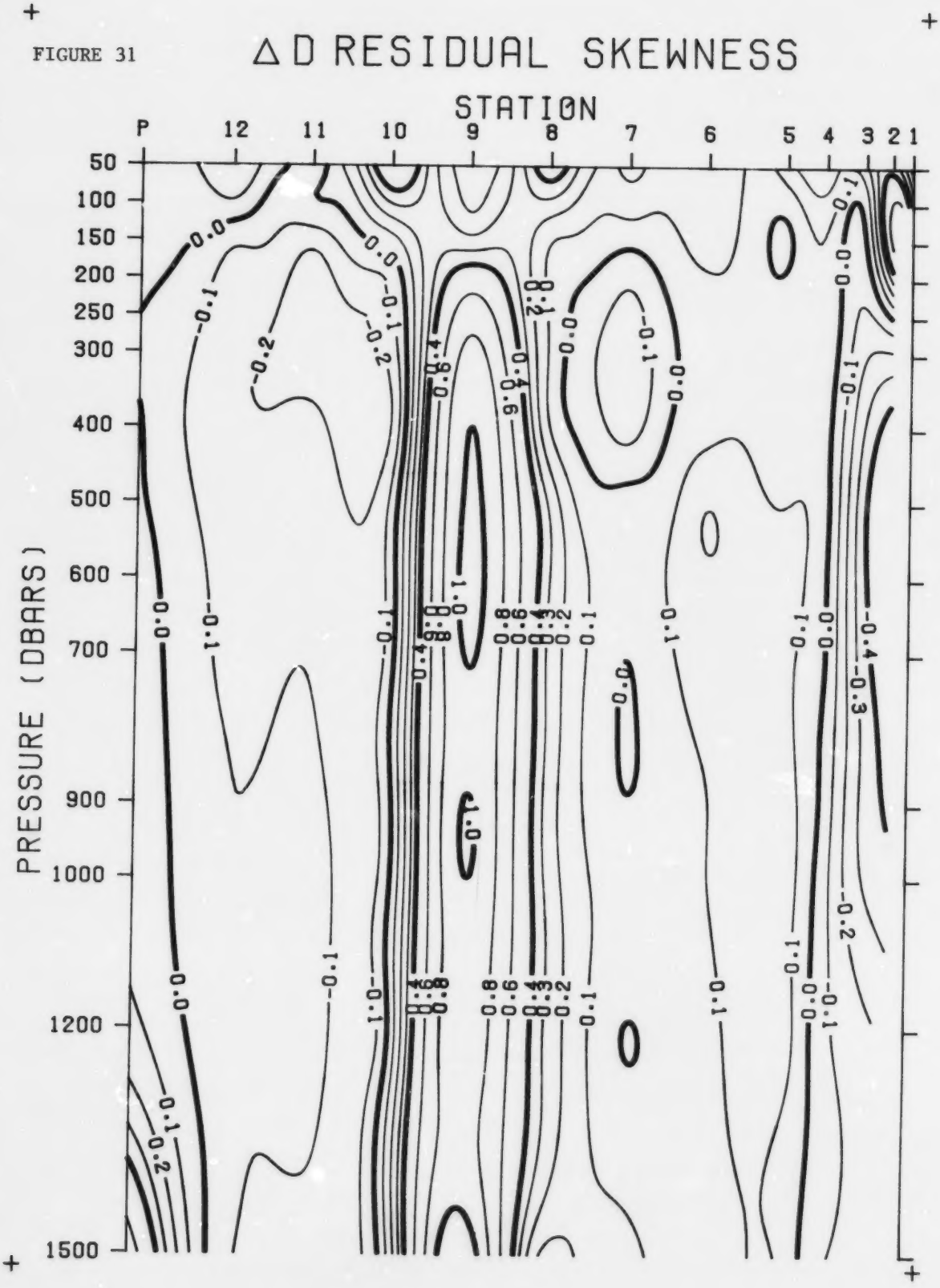

ΔD RESIDUAL SKEWNESS
STATION
P 12 11 10 9 8 7 6 5 4 3 2 1
PRESSURE (DBARS)
50 100 150 200 250 300 400 500 600 700 900 1000 1200 1500

FIGURE 32

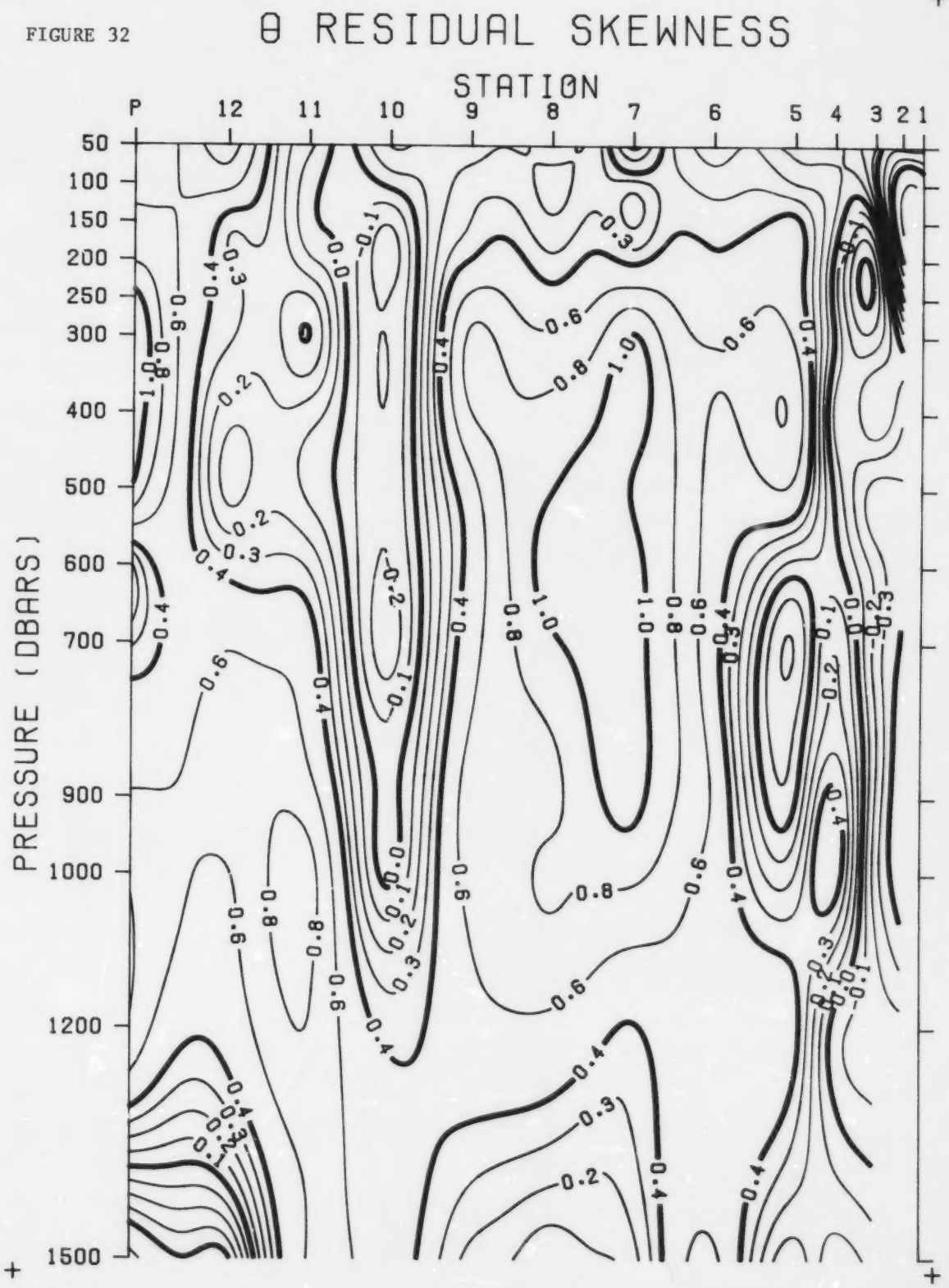

θ RESIDUAL SKEWNESS
STATION
P 12 11 10 9 8 7 6 5 4 3 2 1
PRESSURE (DBARS)
50 100 150 200 250 300 400 500 600 700 900 1000 1200 1500

FIGURE 33

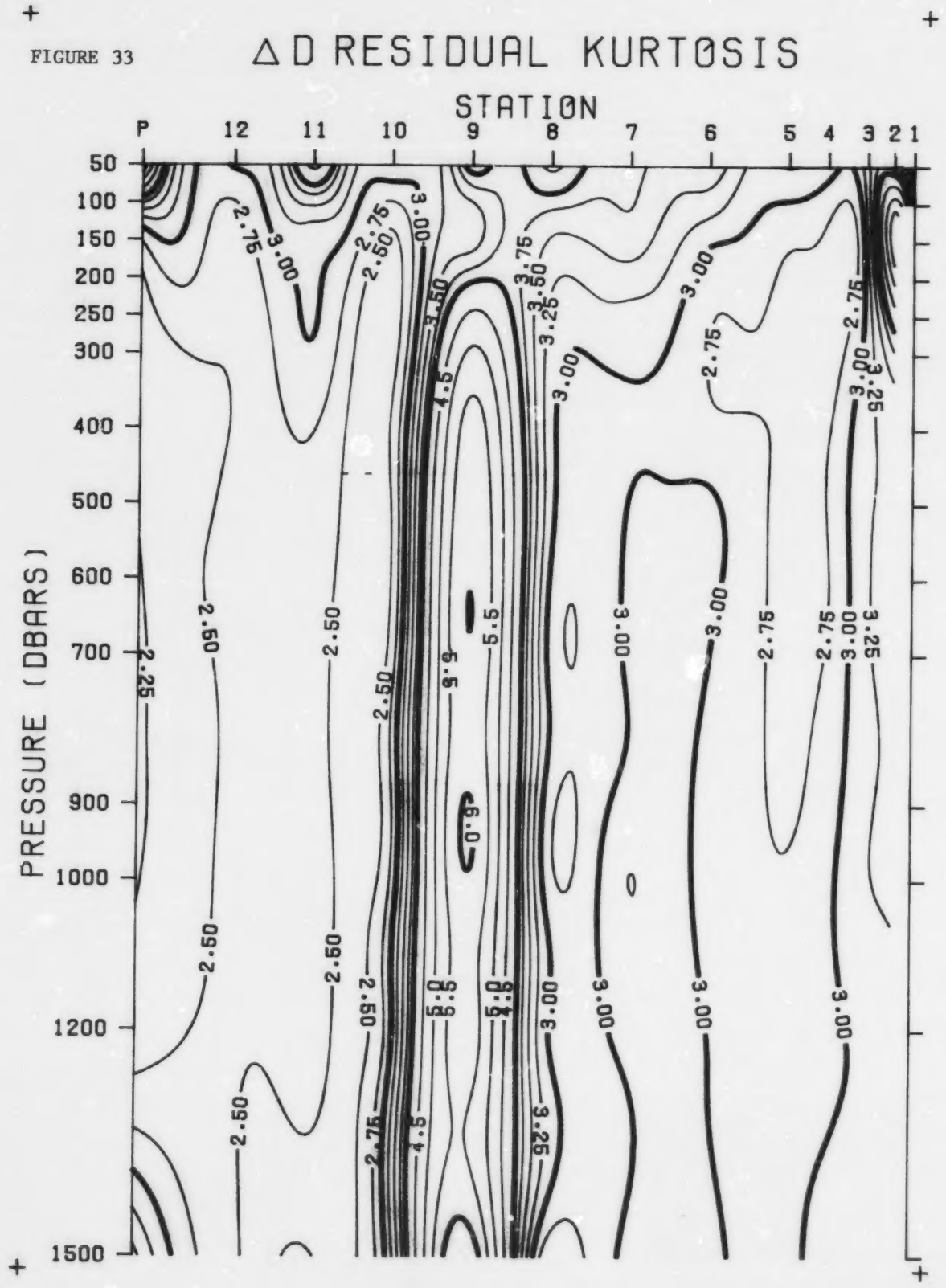

ΔD RESIDUAL KURTOSIS
STATION
P 12 11 10 9 8 7 6 5 4 3 2 1
PRESSURE (DBARS)
50 100 150 200 250 300 400 500 600 700 900 1000 1200 1500

FIGURE 34

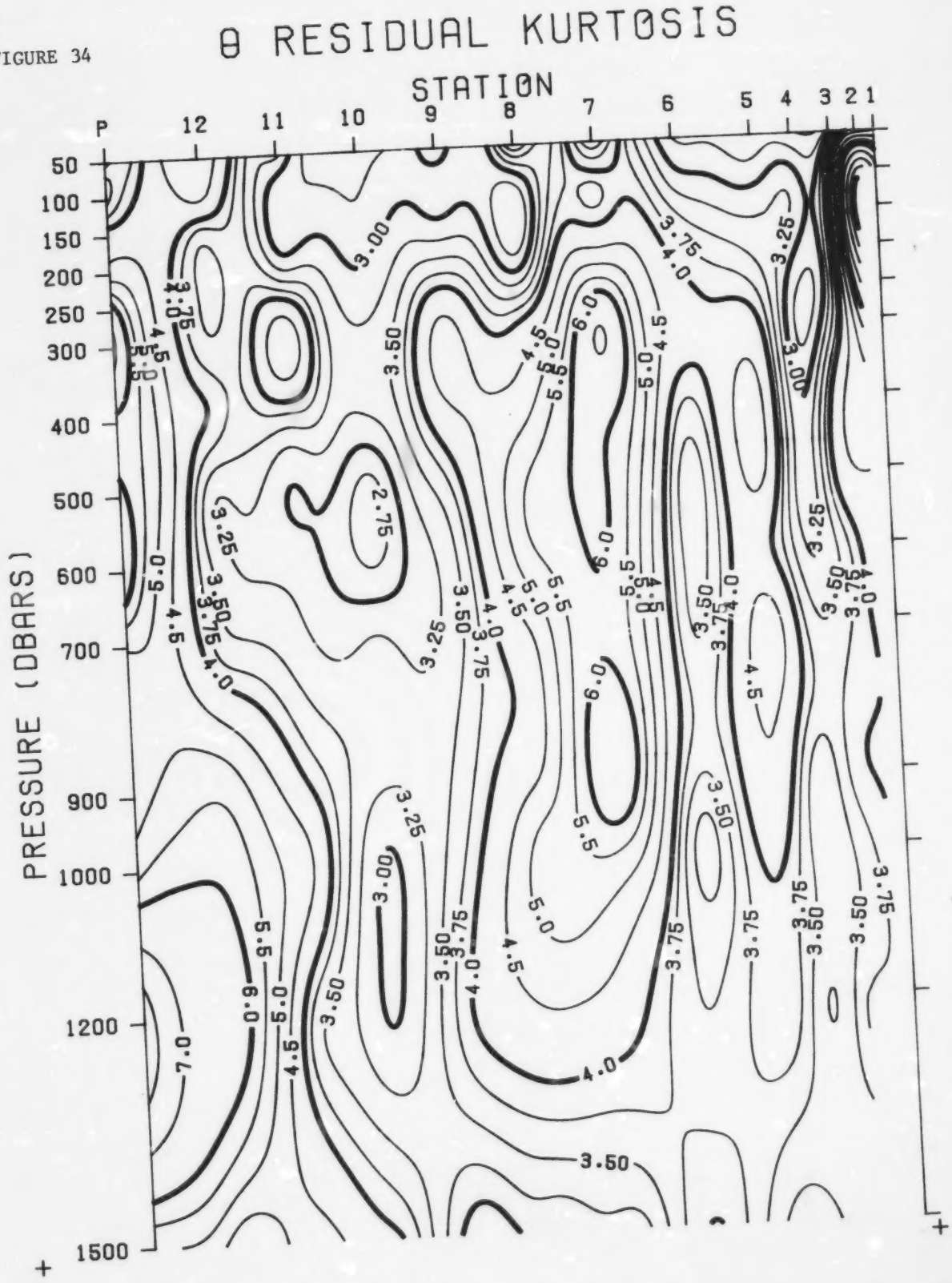

θ RESIDUAL KURTOSIS
STATION
P 12 11 10 9 8 7 6 5 4 3 2 1
PRESSURE (DBARS)
50
100
150
200
250
300
400
500
600
700
900
1000
1200
1500

FIGURE 35

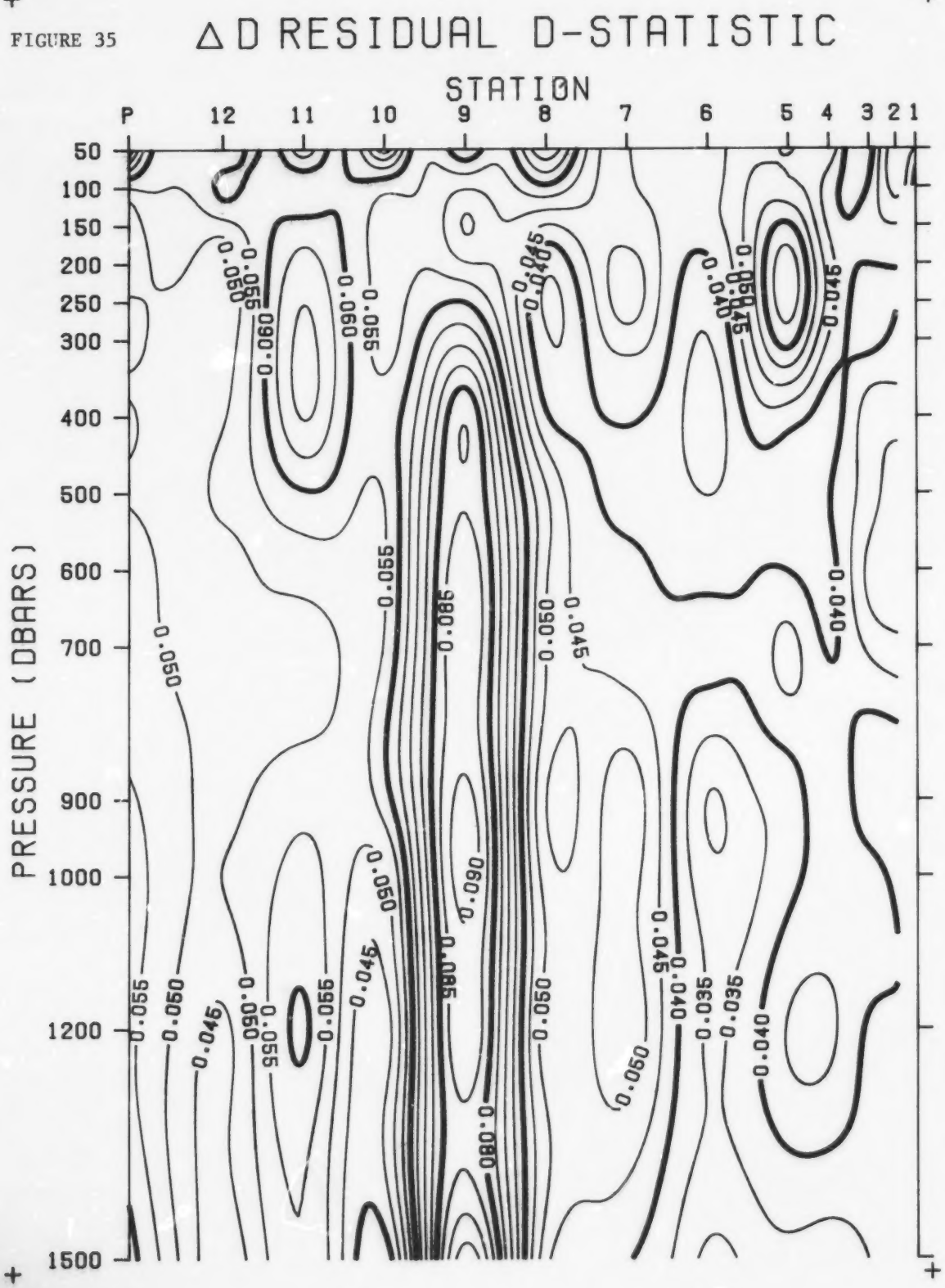

ΔD RESIDUAL D-STATISTIC
STATION
P 12 11 10 9 8 7 6 5 4 3 2 1
PRESSURE (DBARS)
50 100 150 200 250 300 400 500 600 700 900 1000 1200 1500

FIGURE 36

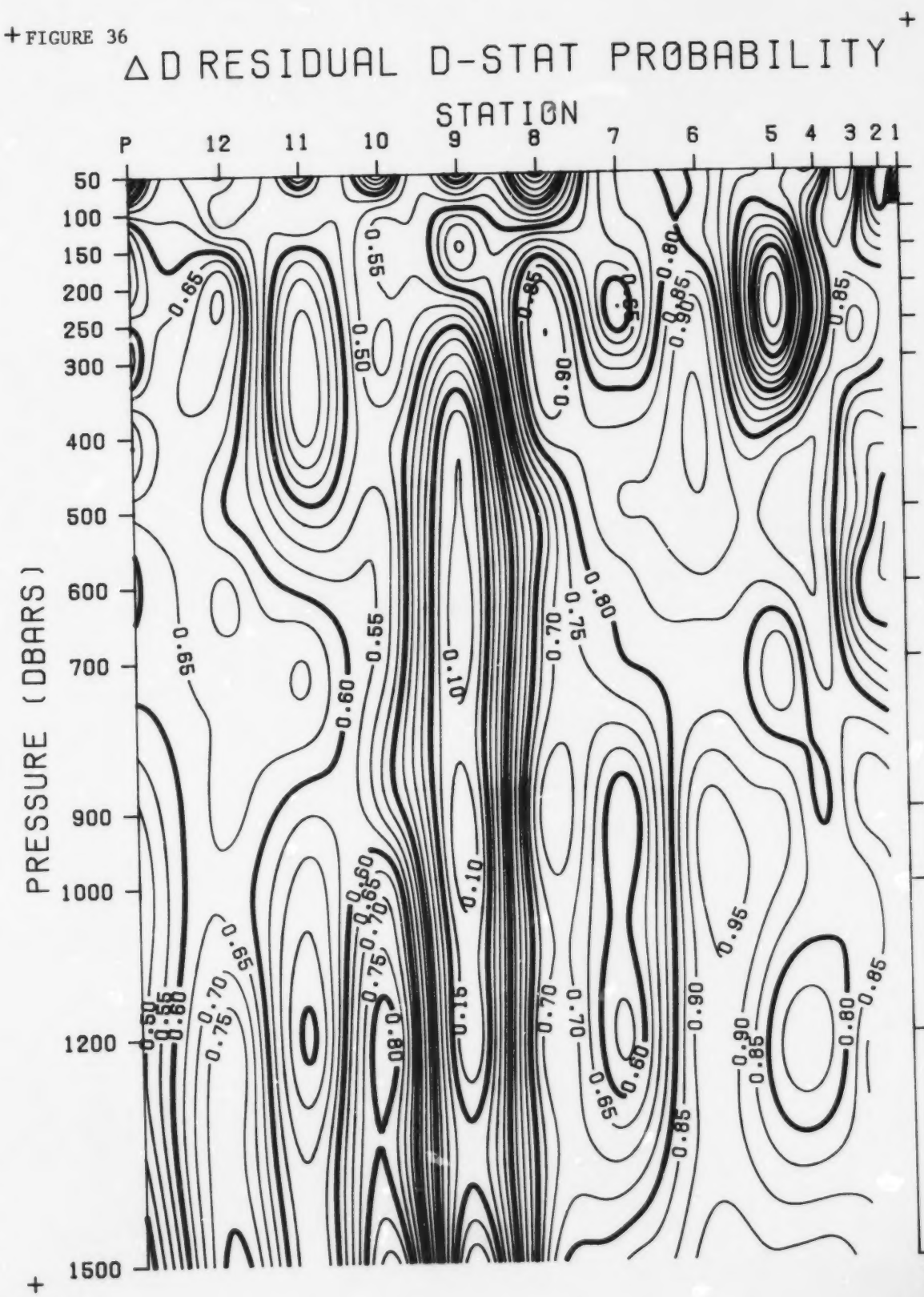

ΔD RESIDUAL D-STAT PROBABILITY
STATION
P 12 11 10 9 8 7 6 5 4 3 2 1
PRESSURE (DBARS)
50
100
150
200
250
300
400
500
600
700
900
1000
1200
1500

FIGURE 37

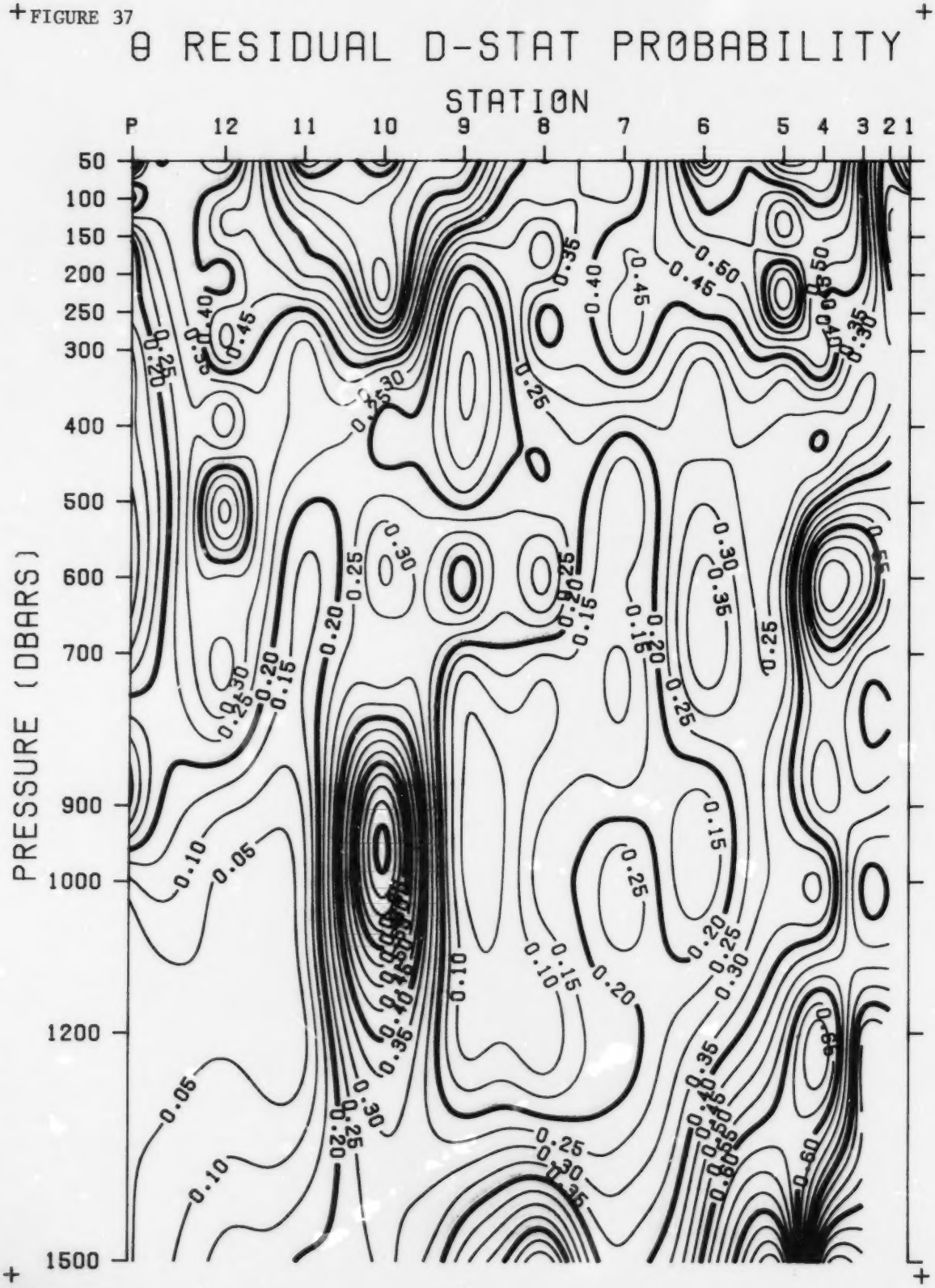
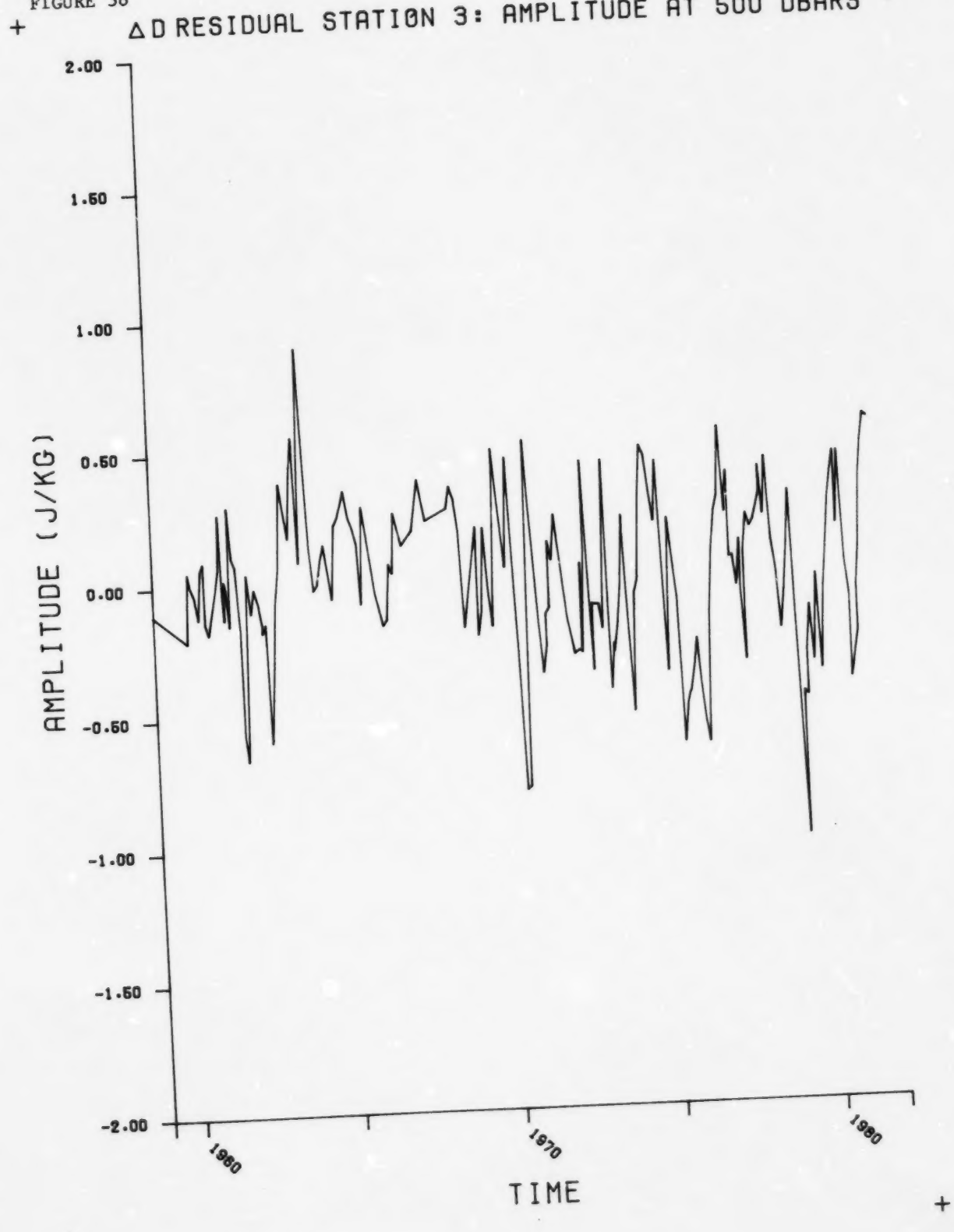

θ RESIDUAL D-STAT PROBABILITY
STATION
P 12 11 10 9 8 7 6 5 4 3 2 1
PRESSURE (DBARS)
50
100
150
200
250
300
400
500
600
700
900
1000
1200
1500

FIGURE 38


ΔD RESIDUAL STATION 3: AMPLITUDE AT 500 DBARS
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
AMPLITUDE (J/KG)
1960
1970
1980
TIME

+FIGURE 39

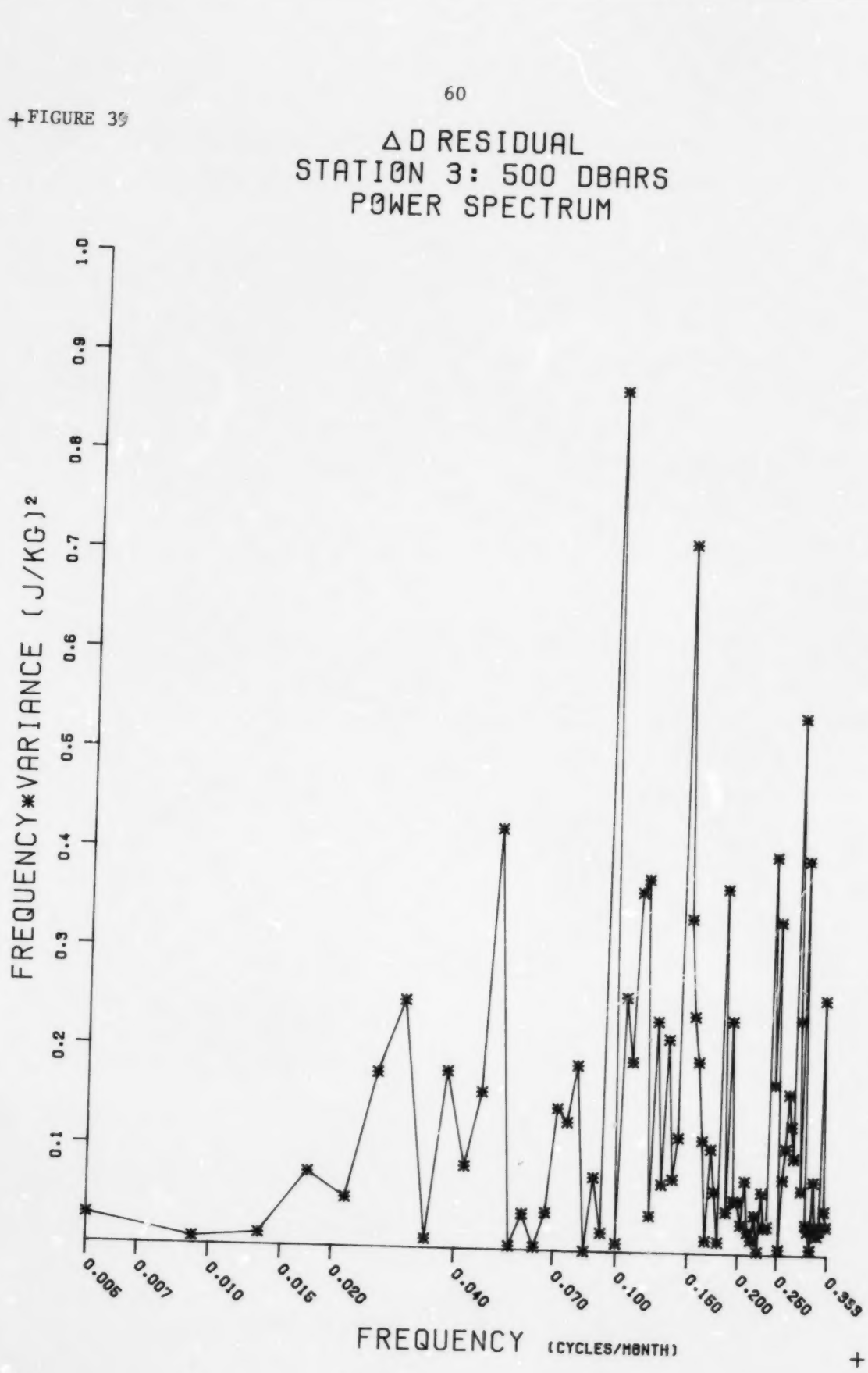

ΔD RESIDUAL
STATION 3: 500 DBARS
POWER SPECTRUM
FREQUENCY*VARIANCE (J/KG)²
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.005
0.007
0.010
0.015
0.020
0.040
0.070
0.100
0.150
0.200
0.250
0.333
FREQUENCY (CYCLES/MONTH)

FIGURE 40

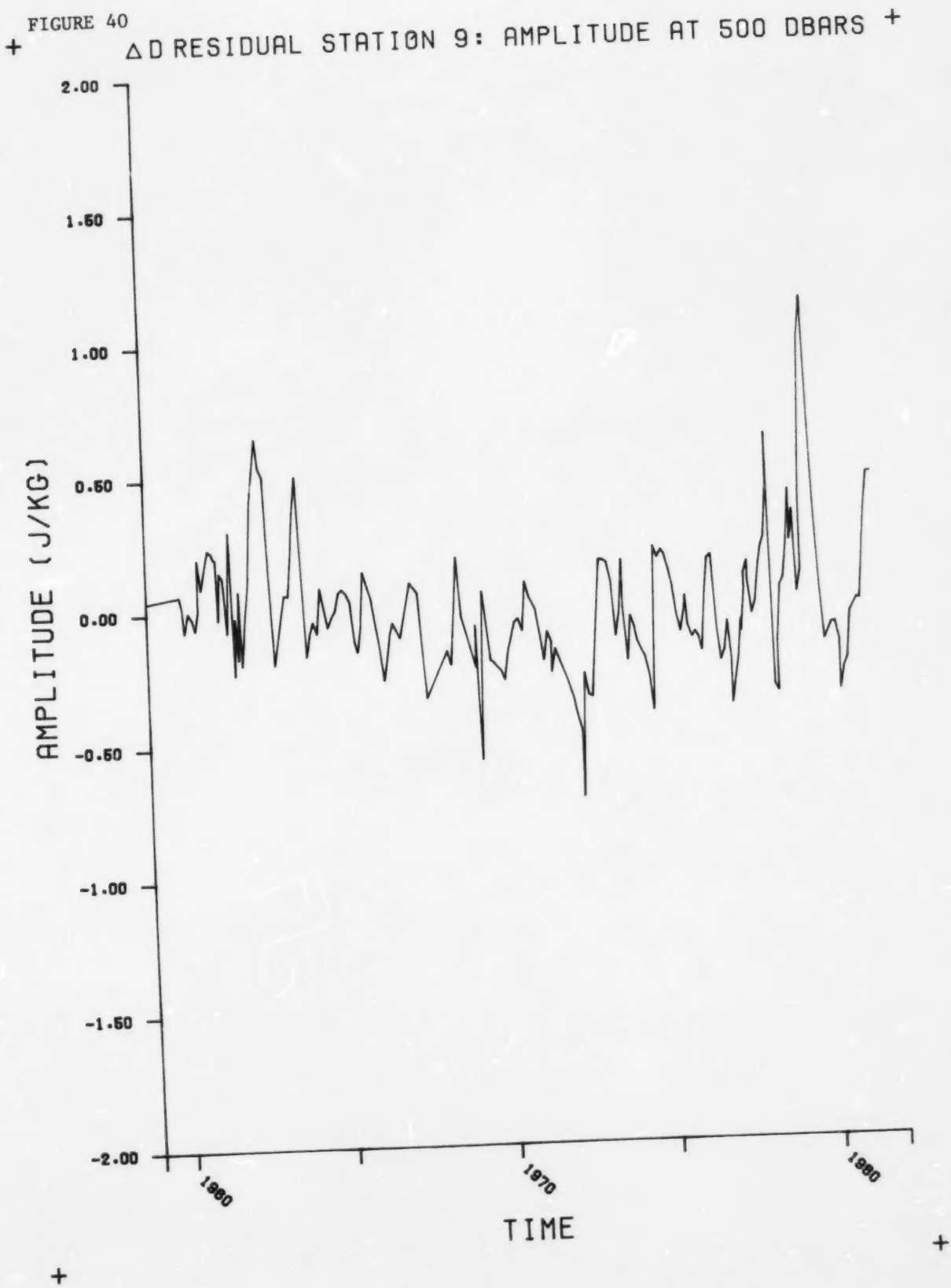

ΔD RESIDUAL STATION 9: AMPLITUDE AT 500 DBARS
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
AMPLITUDE (J/KG)
1960
1970
1980
TIME

FIGURE 41

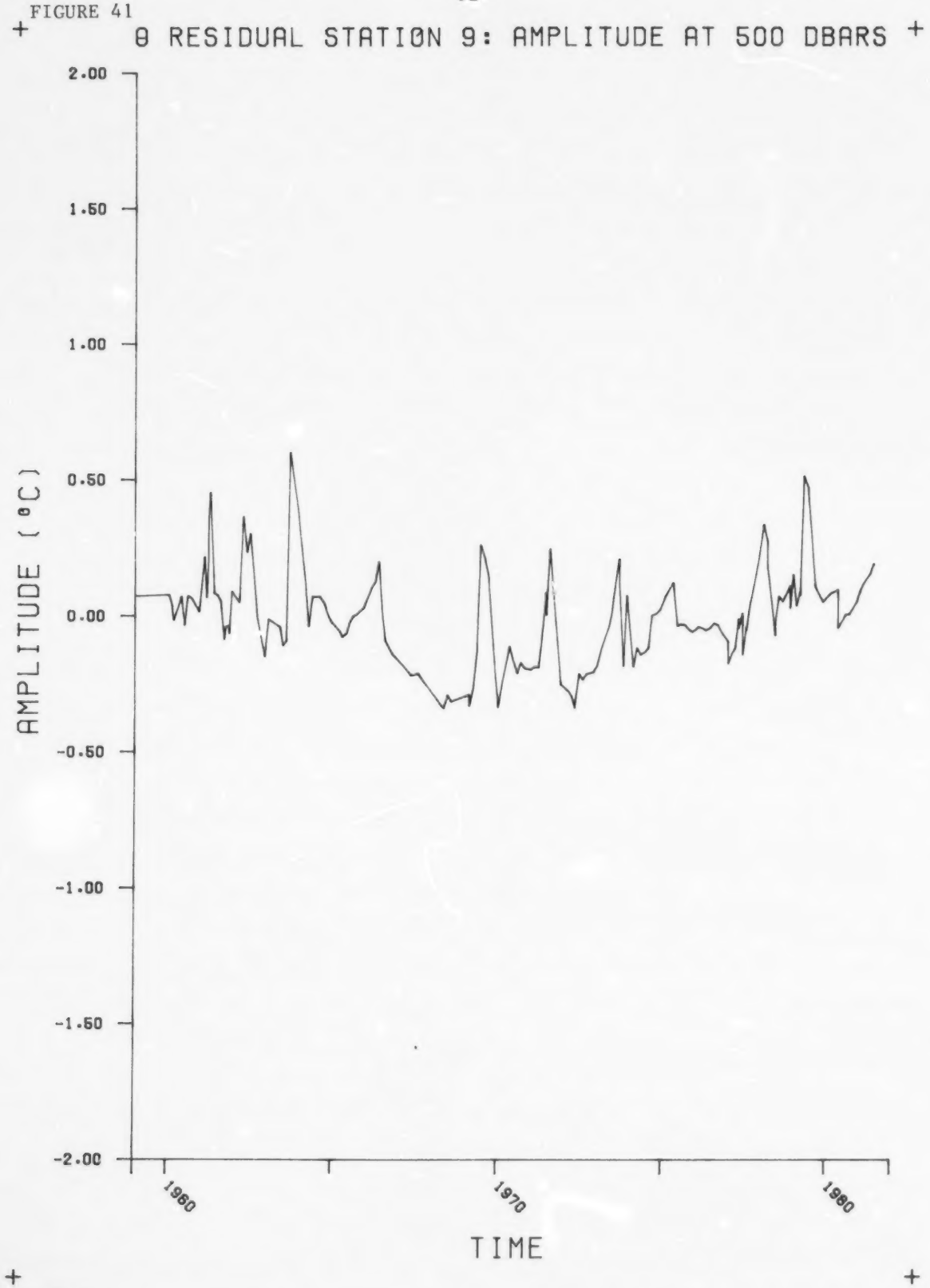

θ RESIDUAL STATION 9: AMPLITUDE AT 500 DBARS
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
AMPLITUDE (°C)
1960
1970
1980
TIME

FIGURE 42

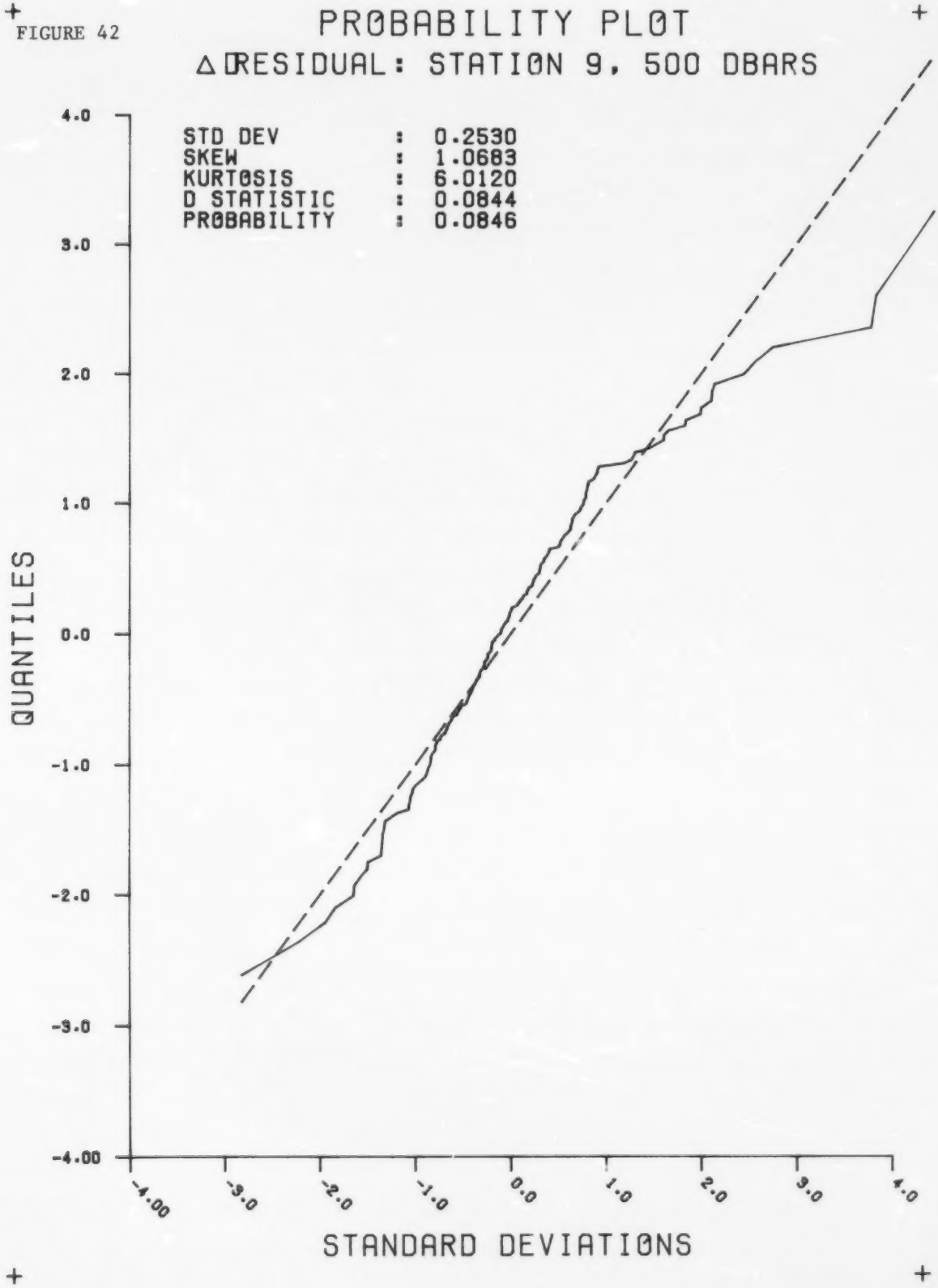

PROBABILITY PLOT
ΔDRESIDUAL: STATION 9, 500 DBARS
STD DEV : 0.2530
SKEW : 1.0683
KURTOSIS : 6.0120
D STATISTIC : 0.0844
PROBABILITY : 0.0846
QUANTILES
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.00
-4.00
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
STANDARD DEVIATIONS

FIGURE 43

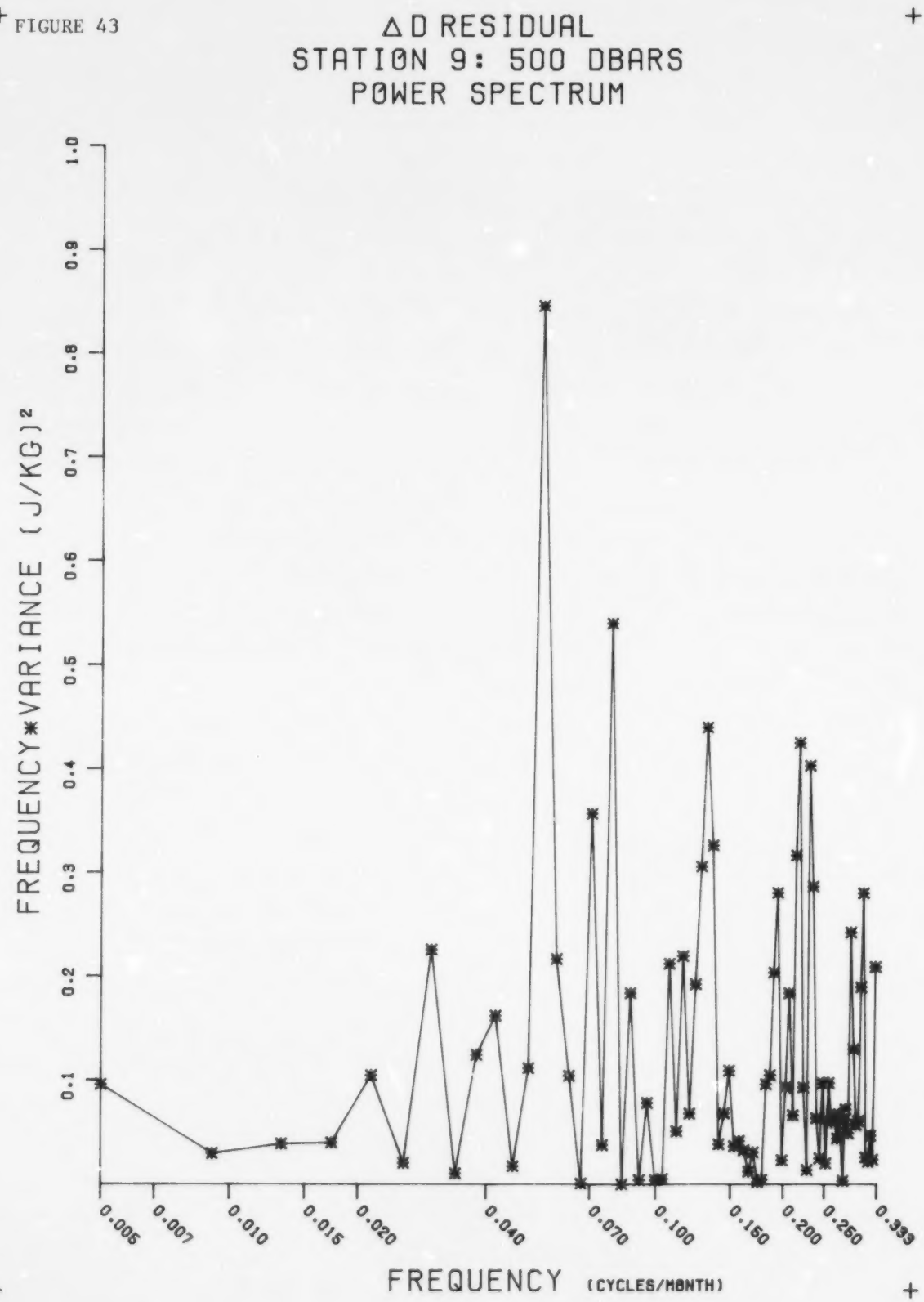

ΔD RESIDUAL
STATION 9: 500 DBARS
POWER SPECTRUM
FREQUENCY*VARIANCE (J/KG)²
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.005
0.007
0.010
0.015
0.020
0.040
0.070
0.100
0.150
0.200
0.250
0.333
FREQUENCY (CYCLES/MONTH)

FIGURE 44

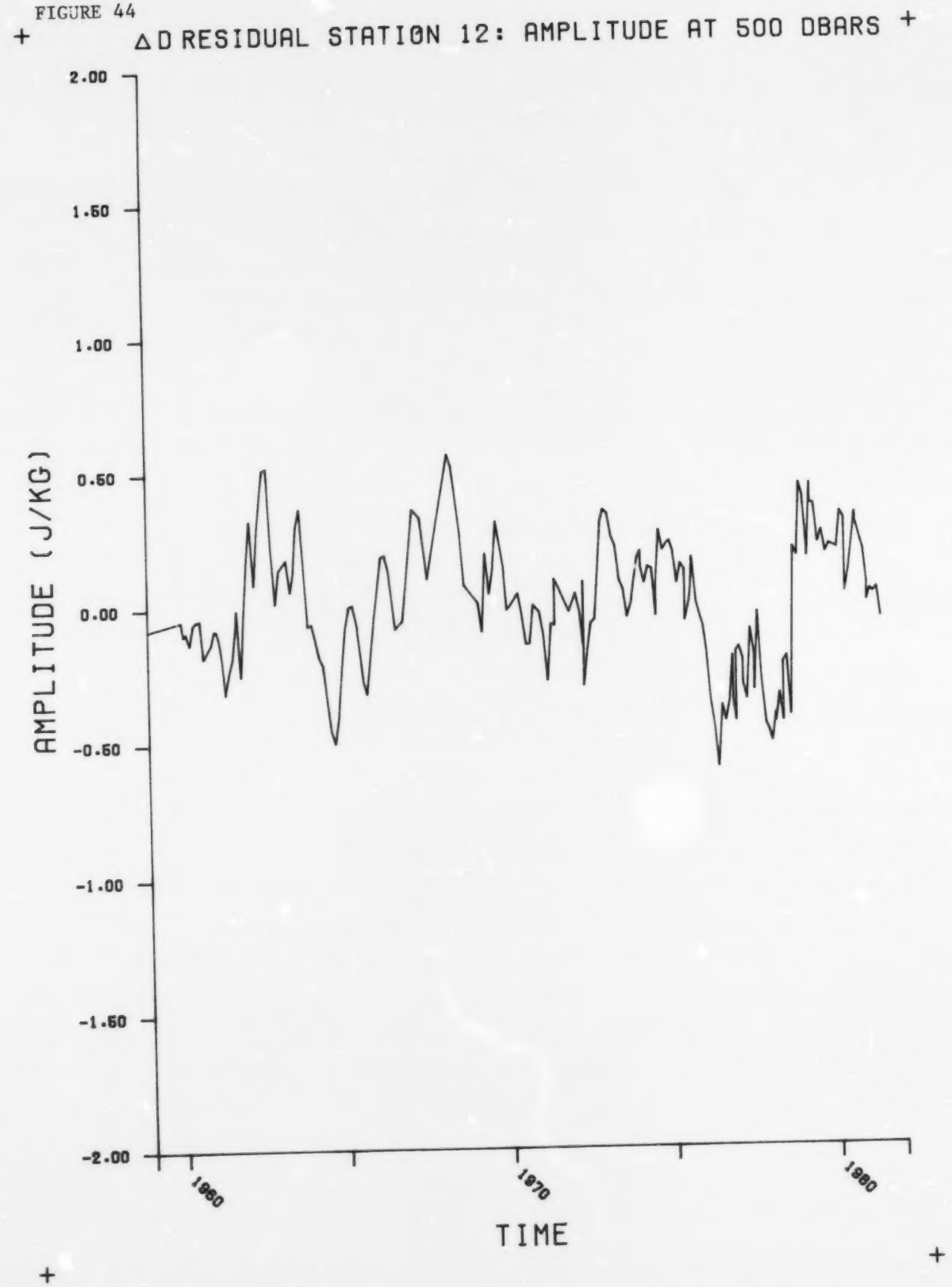

ΔD RESIDUAL STATION 12: AMPLITUDE AT 500 DBARS
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
AMPLITUDE (J/KG)
1960
1970
1980
TIME

FIGURE 45

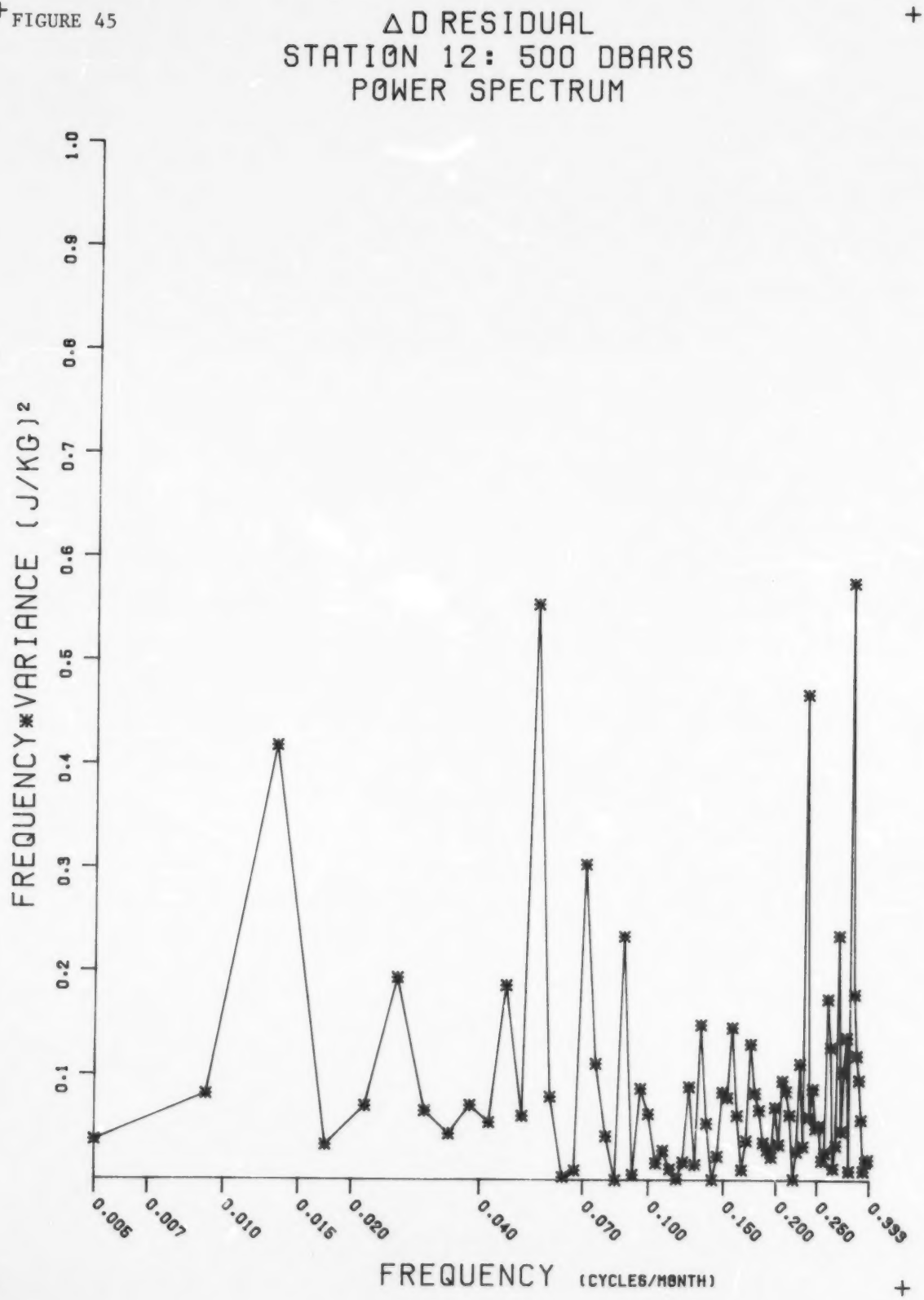

ΔD RESIDUAL
STATION 12: 500 DBARS
POWER SPECTRUM
FREQUENCY*VARIANCE (J/KG)²
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.005
0.007
0.010
0.015
0.020
0.040
0.070
0.100
0.150
0.200
0.250
0.333
FREQUENCY (CYCLES/MONTH)

FIGURE 46

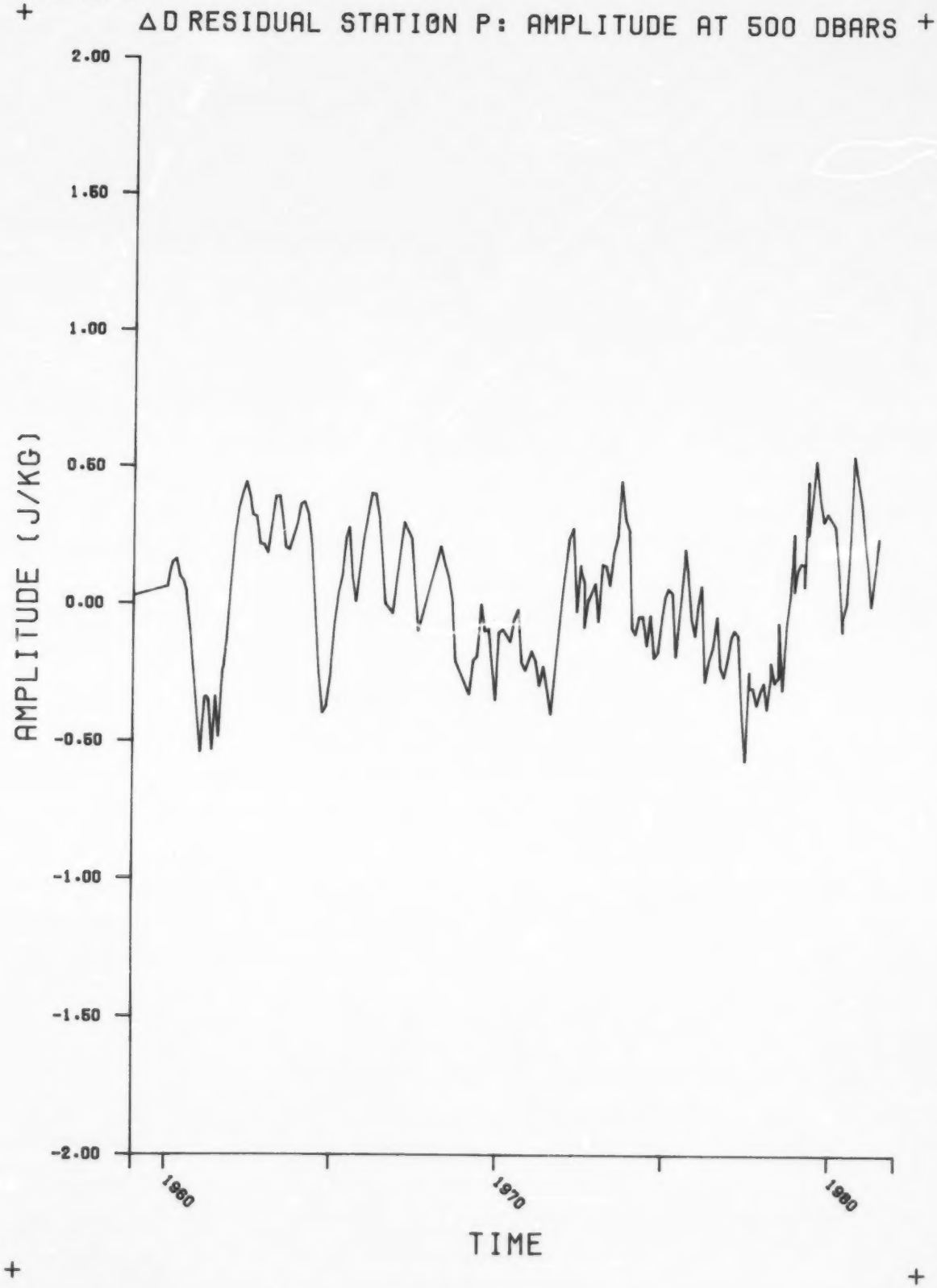

ΔD RESIDUAL STATION P: AMPLITUDE AT 500 DBARS
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
AMPLITUDE (J/KG)
1960
1970
1980
TIME

FIGURE 47

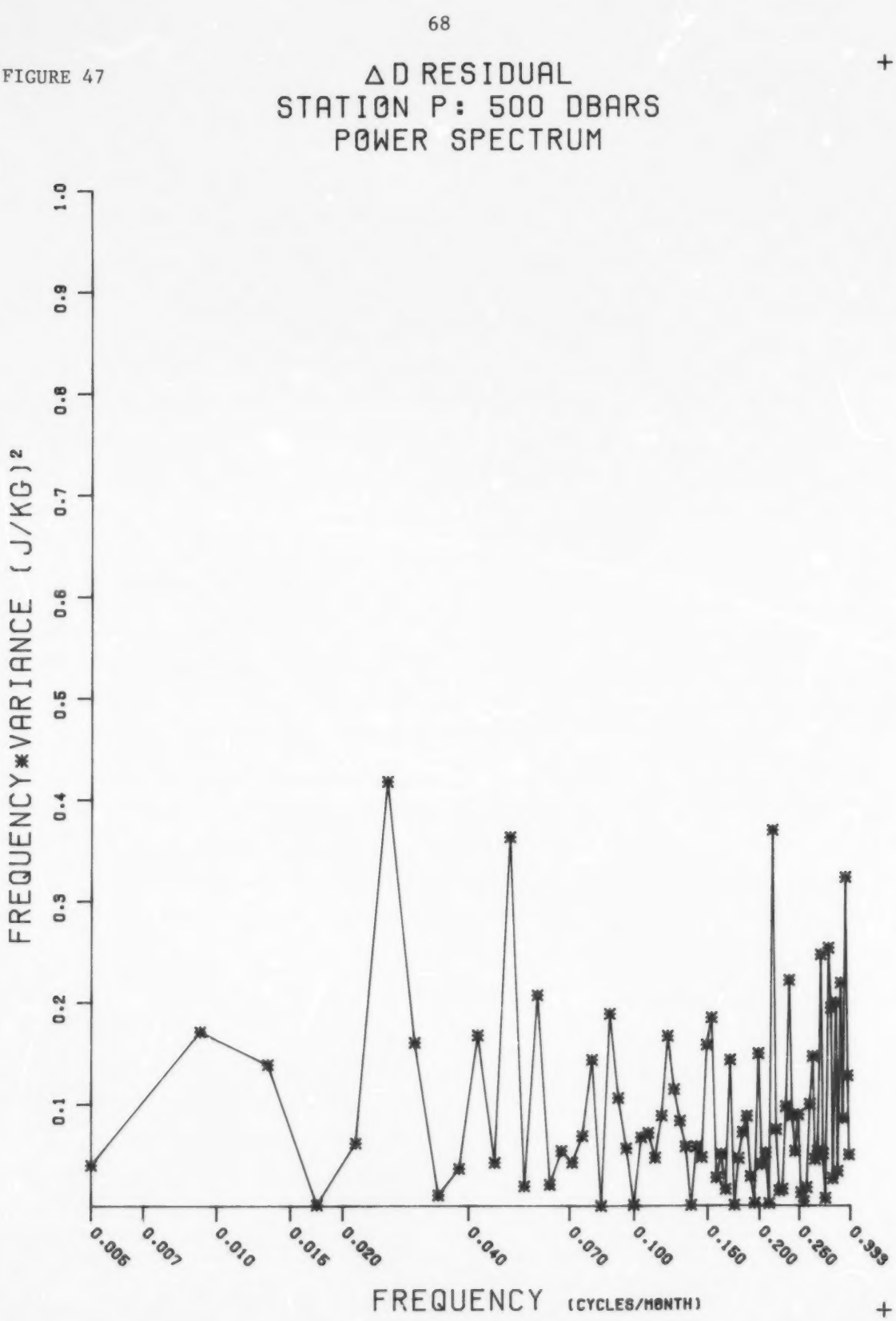

ΔD RESIDUAL
STATION P: 500 DBARS
POWER SPECTRUM
FREQUENCY*VARIANCE (J/KG)²
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.005
0.007
0.010
0.015
0.020
0.040
0.070
0.100
0.150
0.200
0.250
0.333
FREQUENCY (CYCLES/MONTH)

FIGURE 48

θ COVARIANCE: INTERVALS > 1.5 MONTHS
VECTOR 1 AMPLITUDE
POWER SPECTRUM

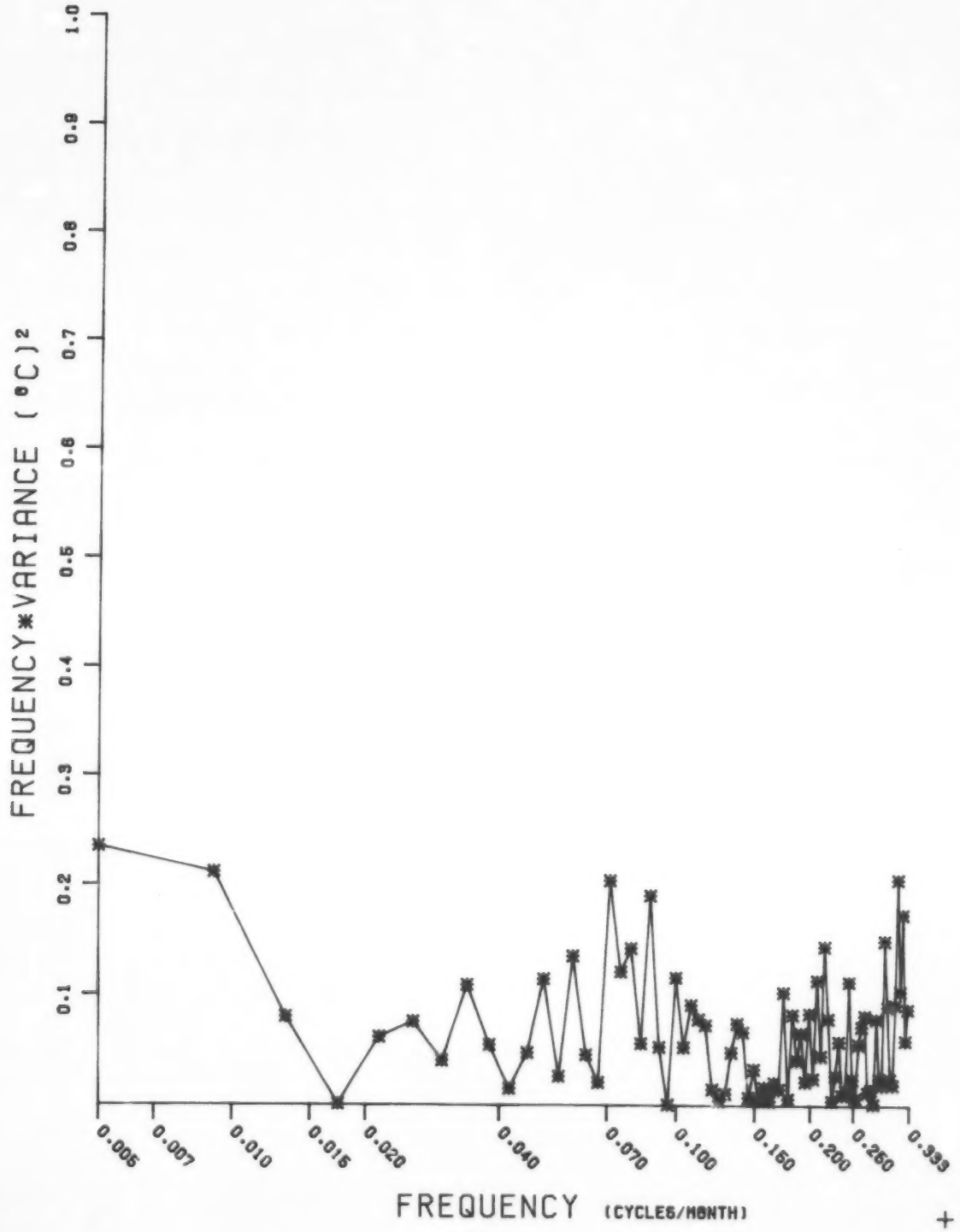


FIGURE 49

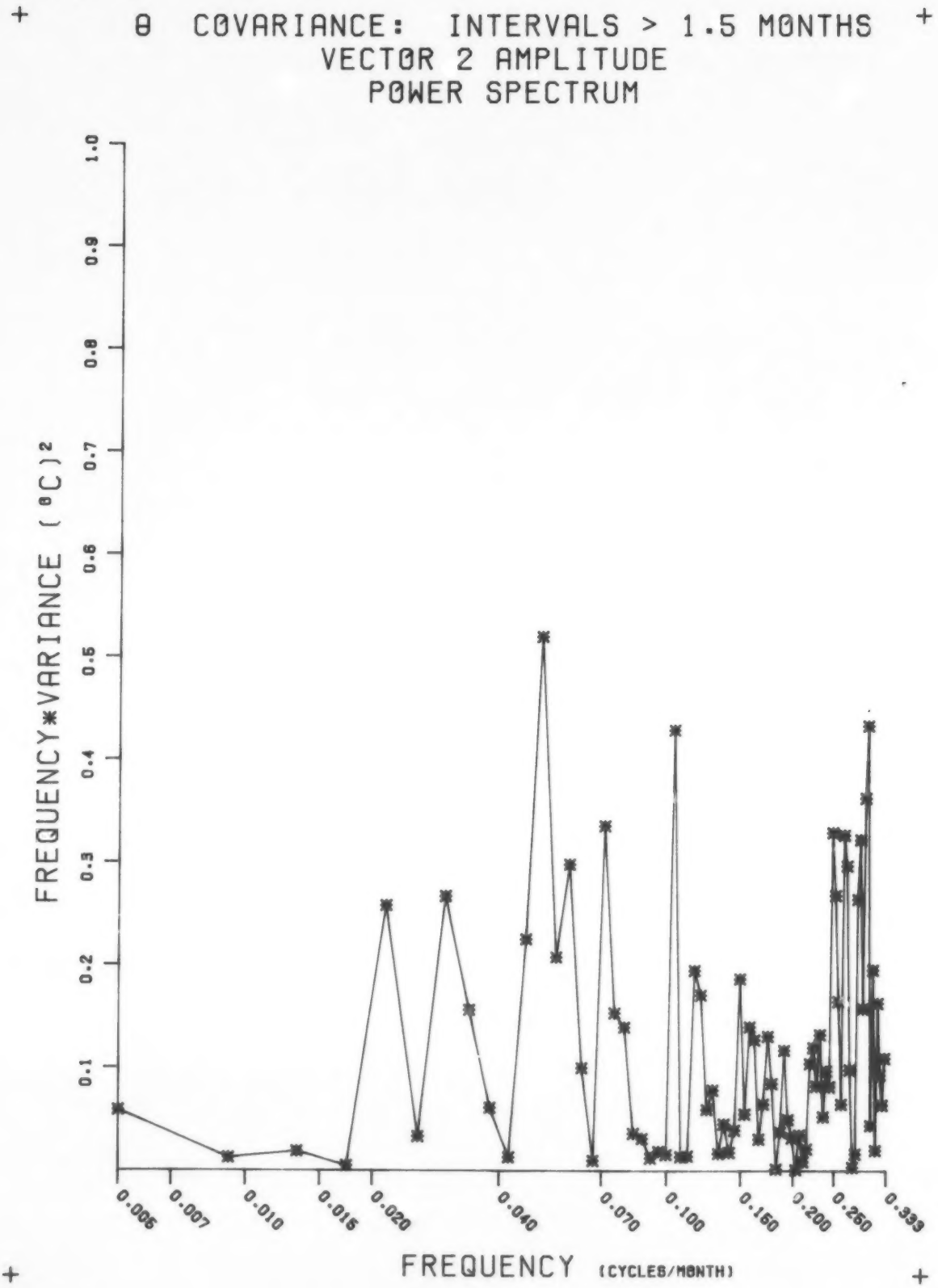

θ COVARIANCE: INTERVALS > 1.5 MONTHS
VECTOR 2 AMPLITUDE
POWER SPECTRUM
FREQUENCY*VARIANCE (°C)²
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.005
0.007
0.010
0.015
0.020
0.040
0.070
0.100
0.150
0.200
0.250
0.333
FREQUENCY (CYCLES/MONTH)

FIGURE 50

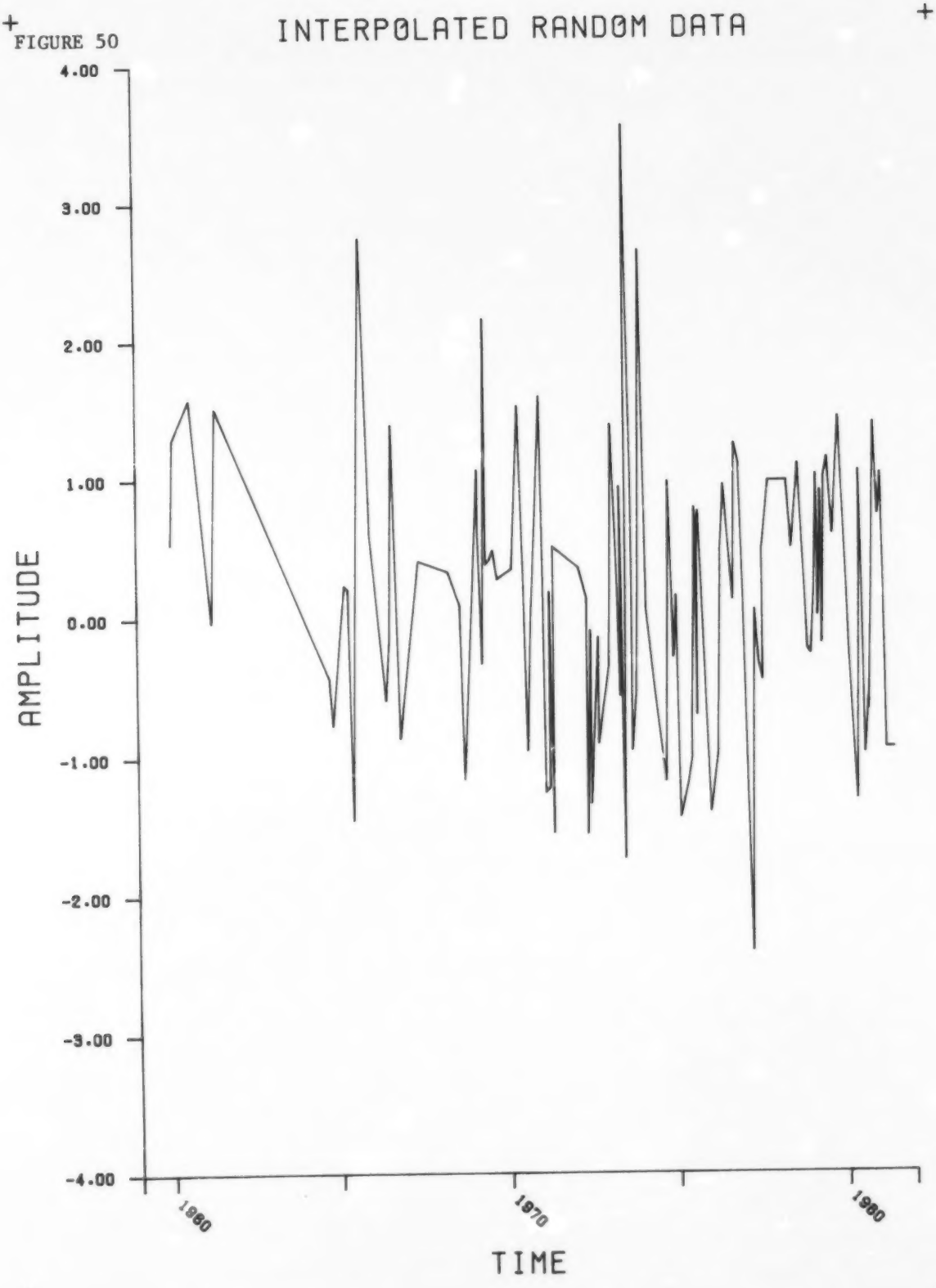

INTERPOLATED RANDOM DATA
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
AMPLITUDE
1960
1970
1980
TIME

FIGURE 51

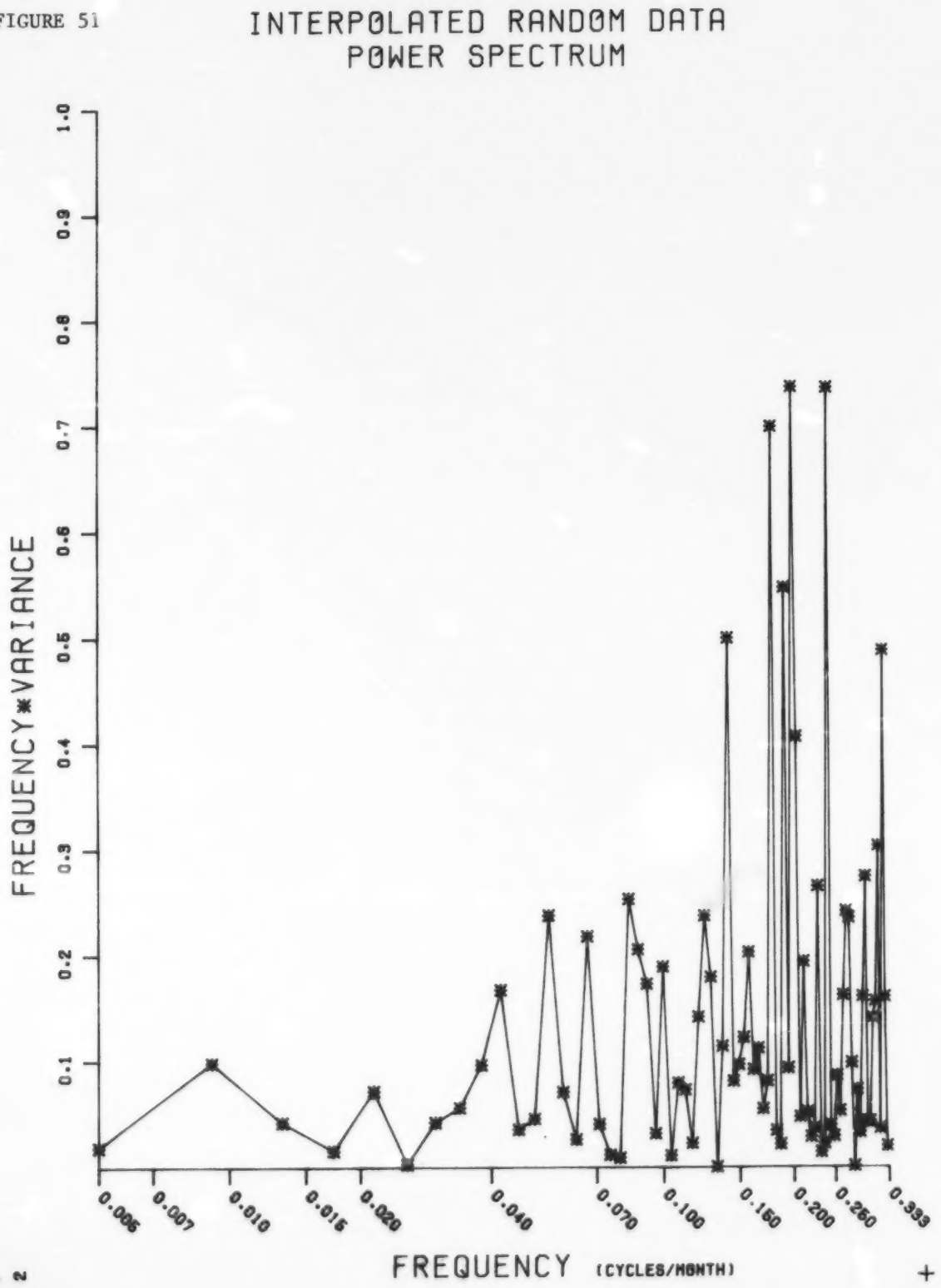

INTERPOLATED RANDOM DATA
POWER SPECTRUM
FREQUENCY*VARIANCE
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.005
0.007
0.010
0.015
0.020
0.040
0.070
0.100
0.150
0.200
0.250
0.333
FREQUENCY (CYCLES/MONTH)

FIGURE 52

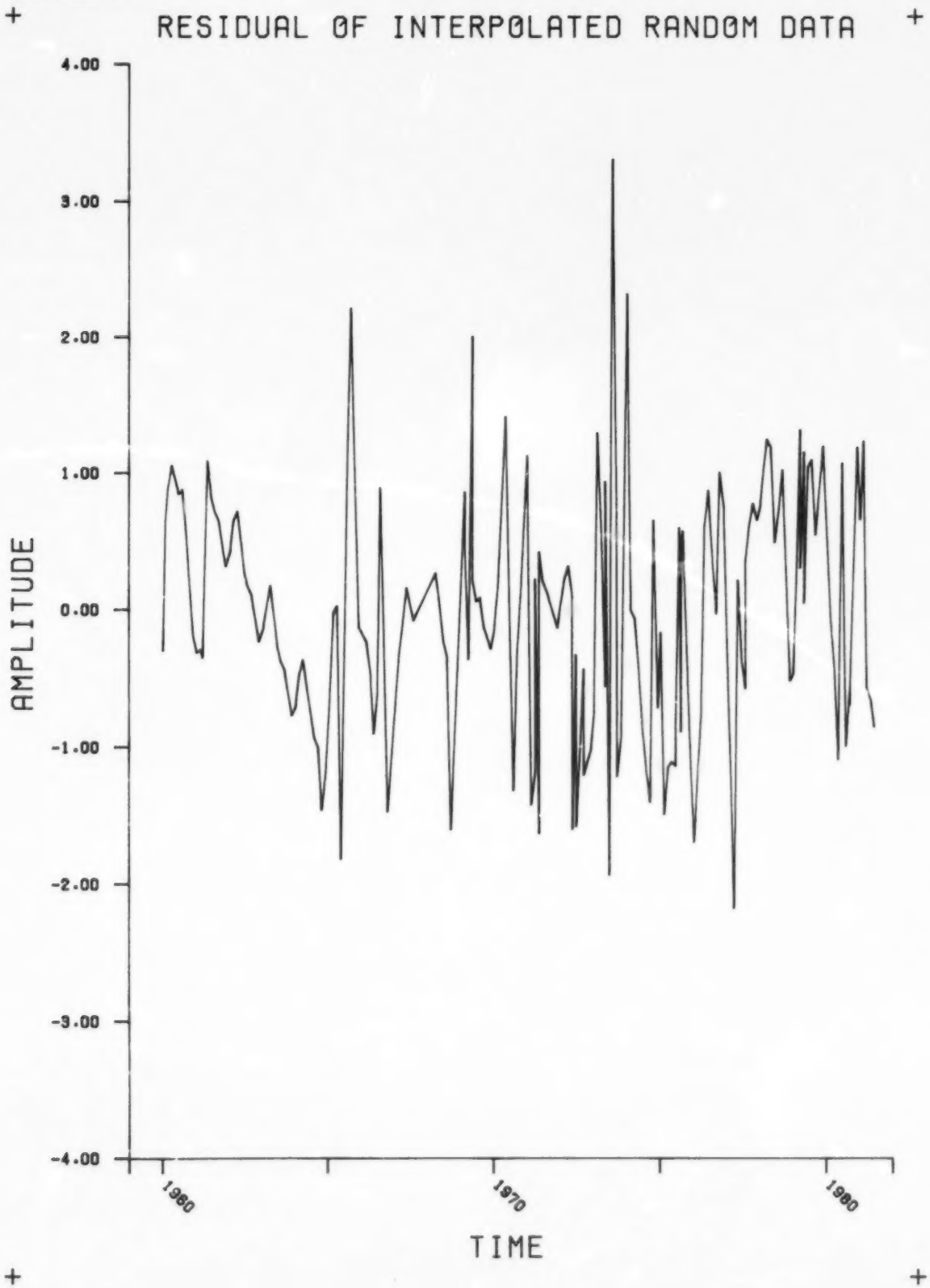

RESIDUAL OF INTERPOLATED RANDOM DATA
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
AMPLITUDE
1960
1970
1980
TIME

FIGURE 53

RESIDUAL 0F INTERP0LATED RAND0M DATA
P0WER SPECTRUM